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FIRST ANNUAL

ACADEMIC APPAREL RESEARCH CONFERENCE

ON

ADVANCED APPAREL MANUFACTURING
TECHNOLOGY DEMONSTRATION

FEBRUARY 14-16, 1990

PHILADELPHIA, PA

PROCEEDINGS

VOLUME 2

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ACADEMIC APPAREL RESEARCH CONFERENCE

on

ADVANCED APPAREL MANUFACTURING TECHNOLOGY DEMONSTRATION

FEBRUARY 14, 1990

Time	Session	Presenter
12:00 - 01:00	REGISTRATION & BOX LUNCH INTRODUCTIONS	
01:00 - 01:45	TEXTILE/CLOTHING TECHNOLOGY CORPORATION	J. OFF
01:45 - 02:30	FASHION INSTITUTE OF TECHNOLOGY	H. SEESSELBERG —
02:30 - 03:15	CLEMSON UNIVERSITY	C. JARVIS
03:15 - 03:30	BREAK	
03:30 - 04:15	GEORGIA TECH/SOUTHERN TECH	J. ADAMS/ — HADDOCK
04:15 - 05:00	NORTH CAROLINA STATE UNIVERSITY	T. LITTLE
05:00 - 05:45	UNIVERSITY OF SOUTHEASTERN LOUISIANA	A. STEWARD
05:45 - 0S:15	PCT&S: MECHANICAL PROPERTIES OF FABRICS	H. BARNDT
06:15 - 06:30	IMPLICATIONS FOR GOVERNMENT AND INDUSTRY	D. O'BRIEN
06:30 - 07:30	RECEPTION	

ACADEMIC APPAREL RESEARCH CONFERENCE

on

ADVANCED APPAREL MANUFACTURING TECHNOLOGY DEMONSTRATION

February 15, 1990

07:30 - 08:30	Registration & Continental Breakfast		
08:30 - 10:30	SIMULATION		
	A LOOK AHEAD	USL	DELCAMBRE
	SIMULATION	TC2	OFF
	DISCRETE EVENT/TROUSERS	GT	SOMMERFIELD/ TINCHER
	LOOK AHEAD SHOP FLOOR	CU	PECK/PARGUS
	OPERATIONS A		
	SUPERVISORY TRAINING	FIT	WALFISH
	COURSE:SUPERVISOR/ ERGONOMICS	GT	ORITZ/KELLY
	PROB. SOLV: PIECE GOODS	CU	CHRISMAN
	ANALYSIS/IMPROVE APPAREL MACHINES	FIT	SCHORR
	MECHANICAL ENGINEERING: A		
	PROB. SOLV: SEW LABELS	CU	ASPLAND
	ATTACHMENTS	TC2	HUGHES
	FLEXIBLE MODULES	NCSU	McPHERSON
10:30 - 10:45	BREAK		
10:45 - 12:45	APPAREL		
	APPAREL MFG DATA BASE	NCSU	CARRERE
	KNOW. BASED FRAMEWORK: TROUSER PROCUREMENT	GT	JAYARAMAN
	KNOW. BASED FRAMEWORK: TROUSER DEFECTS	GT	JAYARAMAN
	ECONOMICS		
	MARKET SURVEY	NCSU	BERKSTRESSER
	INTEGRATED COST MEASUREMENT SYSTEM	CU	McKNEW/ PRATER

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10:45 - 12:45      MATH MODELING
                   DEFINITION: FLEXIBILITY   NCSU  HODGE/CANADA
                   PROB. SOLV: HIERARCHAL    CU    JARVIS
                            PROD. PLAN
                   CUT ORDER PLAN:           GT    JACOBS/
                            TROUSER MFG.                AMMONS
                   PROD.  PLAN.  FOR QR      CU    KANET/DAVIS
                   AUTO.  MARKER MAKING      GT    JACOBS


12:45 - 01:45      LUNCH


01:45 - 03:45      COMPUTER INTEGRATED MANUFACTURING
                   OPERATING SYSTEM FOR      CU    PECK/
                            DISTRIBUTED MFG.         MADISON
                   INTERFACE STANDARDS       USL   DELCAMBRE
                   ARCH. FOR MFG. UTILITY    GT    JAYARAMAN
                            TROUSERS


                   OPERATIONS B
                   COST & PROD. DATA         FIT   KORNGRUEN
                            BUNDLE vs UPS
                   COST & PROD. DATA         CU    HILL
                            BUNDLE vs UPS
                   FLEXIBLE WORK GROUPS      GT    JACOBS
                   FLEXIBLE WORK GROUPS      CU    HILL


                   MECHANICAL ENGINEERING: B
                   PLY SEPARATION            NCSU  CLAPP
                   PROB. SOLV: AIR           CU    ASPLAND
                            FLOTATION
                   ROBOTIC ASSIST: SHIRT     CU    PAUL
                            COLLARS


03:45 - 04:30      FACILITIES TOUR


05:00 - 07:30      RECEPTION & DINNER
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FEBRUARY 16, 1990

07:30 - 08:30   CONTINENTAL BREAKFAST

08:30 - 10:30   APPAREL
DEV. PATTERNS & PROTOS: FIT   JAFFEE
        NAVY, WOMENS
STITCHLESS TECHNOLOGY   CU   JARVIS
IMPROVED MFG. METHODS: FIT   BRENNER
        PEA COATS

MECHANICAL ENGINEERING: B
ROBOTICS FOR PRESSING   RPI   HANNIFIN
DRAPER LABS.   TC2   BERNARDIN
PROGRAMMABLE SEWING M/CS   FIT   SEESSELBERG

OPERATIONS B
PROB. SOLV: CARPEL TUNNEL CU   HILL
MAINTAIN WIP (SOFTWARE   FIT   KAHN
SURVEY)
VIDEO DISC   TC2   HUGHES

10:30 - 10:45   BREAK

10:45 - 12:45   ECONOMICS
NON TRADITIONAL ECO.   CU   KANET
        ANALYSIS
NON TRADITIONAL ECO.   GT   RIALL
        ANALYSIS
NON TRADITIONAL ECO.   FIT   SEESSELBERG
        ANALYSIS

COMPUTER INTERGRATED MANUFACTURING
PROB. SOLV: AGV   CU   PECK
APDES   NIST   HOPP
ELECTRONIC BULLETIN   CU   MADISON
        BOARD

MECHANICAL ENGINEERING: A
AUTO FABRIC INSPECTION   CU   JARVIS
IN-PROCESS QC: FABRIC   GT   TINCHER/
        DEFECTS   DALEY
IN-PROCESS QC: SEWING   GT   OLSON/
        DEFECTS   SIKORSKI

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12:45 - 02:15        LUNCH & CONCLUDING REMARKS

02:15 - 04:15        PLANT TOUR: OPTIONAL
                     DEFENSE PERSONNEL SUPPORT
                     (On the way to the airport)
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FEBRUARY 16, 1990

FASHION INSTITUTE OF TECHNOLOGY

DEVELOPMENT OF PATTERNS AND PROTOTYPES FOR NAVY WOMEN'S UNIFORMS

(PAPER NOT AVAILABLE)

FEBRUARY 16, 1990

CLEMSON UNIVERSITY

STITCHLESS TECHNOLOGY

Stitchless Fabrication of a Chemical Protective Suit

Objective: To develop the manufacturing techniques necessary to construct the Army chemical protective suit using stitchless technologies.

Progress to Date: The primary focus in year 1 is the execution of tasks which represent the primary construction techniques used in fabricating the chem suit. New techniques for forming primary seams, reinforcement techniques, fasteners, bellows pockets, for stamping out small parts, for welding pieces, and for attaching pocket linings are included in year 1. Year 2 is devoted to transfering the knowledge learned in the tasks during year 1 to the actual construction of the entire chemical protective suit.

Progress so far includes the identification of appropriate adhesives and development of adhesive handling techniques as well as identification of fasteners. On-going areas of investigation include design of needed ultrasonic horns for handling assemblies and selection of ultrasonic equipment for forming continuous seams. Stamping out of small parts will be accomplished by laser cutting with edge fusing.

Time frame: Twenty-four months from October 1989

Funding: US Army Natick RD & E

FEBRUARY 16, 1990

FASHION INSTITUTE OF TECHNOLOGY

IMPROVED MANUFACTURING METHODS FOR THE NAVY PEACOAT

FEBRUARY 16, 1990

RENSSELAER POLYTECHNIC UNIVERSITY

ROBOTICS FOR PRESSING

Automated Garment Handling for Pressing:

A Joint Research Effort

by

the Fashion Institute of Technology
Advanced Apparel Manufacturing Technology
Demonstration Center
and
Rensselaer Polytechnic Institute
Center for Manufacturing Productivity
and Technology Transfer

Presented at
the Advanced Apparel Manufacturing Technology Conference

February 16, 1990
Philadelphia, PA

by

Dr. Leo E. Hanifin, Director
Center for Manufacturing Productivity
and Technology Transfer
and
Co-Principal Investigator

Background

In January, 1990, a team of 18 researchers began a project funded by the Defense Logistics Agency aimed at automating garment handling for the pressing operation. The rational for this research is straightforward. While many process steps in garment making have derived considerable advantage from the automated movement of material *during* the process, and many "unit handling" systems have automated the movement of material *between* processes, little has been achieved in the automated *loading and unloading* of the various garment making process operations.

The pressing operation was chosen for several reasons. First, it is a taxing task performed in an inhospitable and potentially dangerous environment. It would therefore be desirable to remove human operators from this environment. Secondly, because of the challenges of seam matching and flattening multiple plys, this has remained a labor intensive operation which demands skillful operators. It therefore would provide an important cost advantage to reduce the labor content in this operation. Third, these same challenges to the human operator provide a significant technological challenge warranting a substantial research program. In fact, if the problems for this task are solved, the results will be applicable to a broad array of operations in garment making and other industries. Finally, it is well known that foreign research organizations have begun to address these issues. (That research is being performed in the closed environment of funded industrial consortia, making the results inaccessible by American manufacturers.) If we are to compete effectively in an international marketplace, we must rise to this technical challenge.

i

General Approach

Objectives of this project are not only to overcome the technological barriers and challenges by developing research results, but also to prove those results in an integrated and operational system and ultimately transfer the results to vendors for commercialization. These three steps, from conception through proof and prototyping, and commercialization roughly map into three one-year phases of the anticipated research effort. The first year will explore enabling technologies in the four areas of (1) modeling, (2) perception, (3) grasping and manipulation, and (4) control/integration. Based on successful research in each of these areas, the second year will integrate each of these results into a prototype system at Rensselaer Polytechnic Institute. The third year will be one of transition of this prototype to commercial products with active and substantial participation of vendors of automation and garment making equipment.

Technical Challenges of Automated Garment Handling

The task selected for the first application of the automated garment handling system will be the pressing of trouser legs. This operation presents a number of technological challenges:

Unknown Location: The trousers are not precisely located prior to pickup by a human operator. Trousers are typically presented to the operator in a large stack or in a unit material handling system. While this is not especially challenging to the human operator, it presents a considerable challenge to an automated system. It is assumed that the automated garment handling system may require that the last person to handle the garment prior to the pressing operation (possibly "seam busting") may be required to hang the garment on the material handling system. While this may provide improved location knowledge to the automated press loading system, it will still not entirely define the overall garment location nor seam location.

Seam Location and Matching: It is important that seams be aligned on top of one another. (Typically within 1/4 " maximum for tailored trousers.) Seams are difficult to perceive with either vision or contact measurement. In fact, most trousers are intentionally designed to mask the seam by matching the fabric at the seam, making seam detection even more difficult.

Loading The Pressing Buck: The laying of the pants flat on the pressing buck presents several difficulties. First, since materials are flexible, no models exist to describe the motion of the fabric as it is grasped, lifted, and possibly stretched into a particular position. It will require an integrate model linked through force and visual feedback to the control system. Finally, the smoothing of fabric once loaded into the pressing buck is typically achieved through a very complex set of motions by the operator interspersed with tactile and vision input and assessment, and finally application of vacuum. In fact, grasping may itself cause difficulties since many techniques create puckers (potential wrinkles) as they attempt to flatten the fabric.

The Research Team: The core research team is located at Rensselaer Polytechnic Institute, and is comprised of 14 individuals from two academic departments and two centers. The two participating academic departments are Mechanical Engineering, Aeronautical Engineering and Mechanics (MEAEM) and Electrical Computer and Systems Engineering Departments (ECSE). The Centers are the Center for Manufacturing Productivity and Technology Transfer (CMPTT) and the Rensselaer Design Research Center (RDRC). These participants are divided into four

1

teams addressing the four areas of enabling technology. These four teams are structured according to Figure 1 and are led by the following principal investigators:

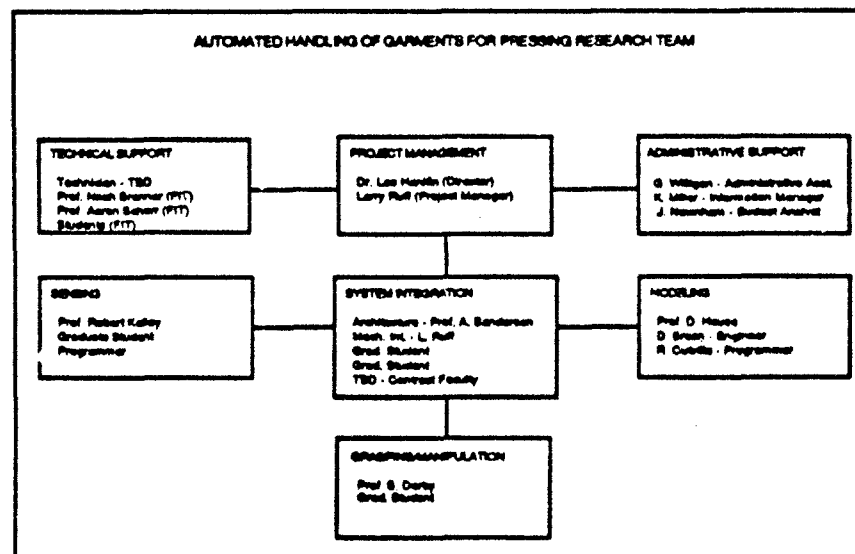|	
Modeling:	Professor Don House - RDRC
Sensing:	Professor Robert B. Kelley - ECSE and CMPTT
Grasping/Manipulation:	Professor Stephen Derby - MEAEM, and CMPTT
System/Integration:	Professor Arthur Sanderson - ECSE and CMPTT
	Lawrence Ruff - CMPTT

Figure 1

The overall team is coordinated by Dr. Leo E. Hanifin and involves an additional four graduate students, two programmers, one engineer and one technician.

In addition to the core team at Rensselaer, the Fashion Institute of Technology is providing guidance on the current state of garment manufacturing and garment making technology. This team is led by Professor Aaron Schorr, with participation of Noah Brenner, both of the Advanced Apparel Manufacturing Technology Demonstration Center (AAMTD) and several students.

Vendor Partners

To date, two corporations have committed support to the Automated Garment Handling Project: these are General Motors Fanuc Robot Company and Hoffman/New Yorker. Both companies occupy a position of leadership in their respective fields with GMF the largest manufacturer of robots in the country, and Hoffman/New Yorker the largest manufacturer of pressing equipment in the country. As such, they offer effective resources for equipment and software, guidance in their fields, and commercializaiton of results. GMF is providing to the effort, an S-700 Robot with the advanced KAREL control system and two-camera vision system. This is shown in Figure 2.
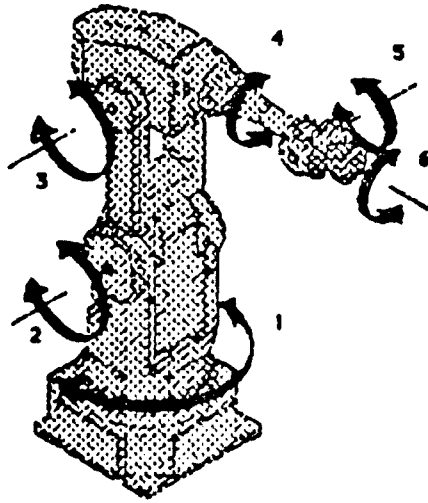
2

Figure 2

Hoffman/New Yorker is providing both equipment and technical manufacturing support. The equipment is primarily a Hoffman Universal Press Model #UAL135 pressing system, shown in Figure 3. In addition, Hoffman has agreed to provide design and manufacturing support services to modify and/or extend their system.
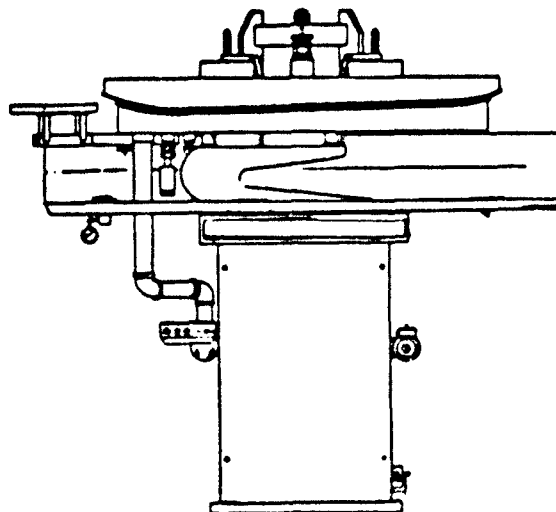
Figure 3

Past Related Research

While Rensselaer has not, in the past, been active in garment making research, it has become a national center for manufacturing education and research. Many past research efforts can bear directly on this project providing foundation of knowledge and expertise.

Past Modeling Research: Rensselaer's Design Research Center (previously the Center for Interactive Computer Graphics) has for nearly two decades been recognized as a national center of excellence in solid modeling. Recent research efforts in RDRC have focused on the modeling of non-solid materials such as fluids, molecules, and human tissue.

The RDRC's efforts in modeling span a broad range of topics. Early research focused on the development of geometric modeling pirmitives, namely the sur rquadric, and their use in Constructural Solid Geometrics (CSG) models. Extensive resear h has also been conducted in the area of Finite Element Modeling (FEM). Current modeling efforts at the RDRC focus on automatic tolerancing of geometric models, feature-based design and particle-based modeling.

Perception Research: Rensselaer's research efforts in perception systems in general, and particularly in vision, have been widely recognized for their results in the software development for image acquisition, image enhancement, and interpretation as well as applications to a variety of manufacturing processes. The team leader in this area, Dr. Robert B. Kelley, with 17 years experience in the business, has directed nationally recognized robotics research initiatives in bin picking, and has recently focused on 3-dimensional and color vision for object recognition, manipulation and inspection.

Grasping and Manipulation: Professor Stephen Derby has, for 12 years, been the leader in mechanical robotic systems. In addition to Doctoral level research in relevant areas, he has directly participated in the CMPTT efforts involving the handling of composite materials with strong similarities to garment making. These efforts also involved Lawrence Ruff. Dr. Derby has been involved with many other industrially sponsored robot gripper and materials handling designs.

Control/Integration: The Center for Manufacturing Productivity has, for 6 years, operated a research program in computer integrated manufacturing which involves 40-60 researchers at a time. This and other efforts in workcell and machine control provide a general resource for system/control engineering. The Principal investigators in this area provide a complement of control architecture and mechanical integration capabilities. Professor Arthur Sanderson is a national leader in robotics controls and control architecture, and is currently President of IEEE's Robotics and Automation Society, and Chairman of the ECSE Department. He has developed a series of multirobot flexible assembly workcells, is currently engaged in research on interactive planning and design environments for flexible manufacturing systems. Lawrence Ruff, CMPTT project manager, has 16 years experience in the design and integration of machine tools for both industry and manufacturing research. Mr. Ruff has recently developed a completely operational and fully integrated small lot sized assembly system which involves two robots, hand changing, and vision and force sensing.

Early Efforts and Approaches

Initial efforts will focus on three objectives of learning from ongoing garment making research, learning the needs of the process from the garment makers and equipment vendors, and exploratory research. With regard to the discussion cf ongoing research. During the first quarter of its effort, the team will visit several nationally recognized centers of garment

4

making knowledge, including the Fashion Institute of Technology, Textile and Clothing Technology Center, North Carolina State, Clemson and Georgia Tech. In addition to visits to these research centers, the team will visit appropriate garment makers and equipment vendors. Visits have already been made to Pietrafesa, in Syracuse, New York, and Hoffman/New Yorker.

In addition to studies of the garment making facilities and vendors and garment making research, the team will investigate other sources of knowledge in the domain of four enabling technologies (modeling, vision, grasping/manipulation and control/architecture).

Simultaneous with these investigations, experimental research will be undertaken to explore specific technological concepts aimed at meeting the functional objectives of the system. These preliminary investigations will look into such areas as:

- Use of parallel architectures to speed detailed model computation.

- Extension of particle modeling concepts to represent threads in woven fabric.

- Intense backlighting for through-fabric seam detection.

- Roller/Gripper designs for seam alignment.

- The application of the Advanced Manufacturing Research Facilities (AMRF) real-time control concept/system (RCS) for integrated device control.

These experiments will employ a substantial array of equipment which is either now installed or committed from vendor partners:

- GMF S700 robot with KAREL controller and two camera vision system

- IBM two-arm robot

- Hoffman/New Yorker pressing system

- Silicon Graphics 4D/60 workstation

Following these preliminary experiments, the remainder of "Year One" will be dedicated towards creating functional subsystems which achieve the required modeling, perception, manipulation and control functions. These capabilities will be demonstrated on the GMF - Hoffman workcell.

Year Two - Integration

Once these systems have been created they will be linked together in hardware and software in such a way that the models, sensory systems, and control systems provide required information and interpretation to one another. This will be first done on a "look-then-move" sequence. Later during the second year, this will be integrated through the architectural concepts into a simultaneous look and move process, thereby accelerating the loading process.

Year Three - Transfer and Commercialization

During the third year, the principle objective will be the transformation of a fully functional laboratory prototype into a commercial product, or a series of products. These prototype systems will be made more robust, and thoroughly documented so that they can be installed and

5

maintained in a typical garment making facility. In order to accelerate this transfer, a number of organizations from Rensselaer will work through extension agents and factory beta sites. In particular, the NYS Center for Advanced Technology in Automation and Robotics and the Northeast Manufacturing Technology Center will work with industrial extension agents in New York to identify and prepare beta sites for the introduction of this technology. Other partners, such as Hudson Valley Community College and Fashion Institute of Technology, will work with companies to prepare technical staff to support the system after its implementation in the factory.

If successful, this effort will execute a seamless flow of knowledge from creation through proof and integration, to commercialization and implementation on the factory floor. The result will be an advanced material handling system which provides a powerful competitive weapon to American garment makers.

6

FEBRUARY 16, 1990

DRAPER LABS

(PAPER NOT AVAILABLE)

FEBRUARY 16, 1990

FASHION INSTITUTE OF TECHNOLOGY

PROGRAMMABLE SEWING MACHINES

(PAPER NOT AVAILABLE)

FEBRUARY 16, 1990

CLEMSON UNIVERSITY

CARPEL TUNNEL SYNDROME

(PAPER NOT AVAILABLE)

FEBRUARY 16, 1990

FASHION INSTITUTE OF TECHNOLOGY

SURVEY OF SOFTWARE FOR WIP

(PAPER NOT AVAILABLE)

FEBRUARY 16, 1990

TEXTILE/CLOTHING TECHNOLOGY CORP.

VIDEO DISC TRAINING

(PAPER NOT AVAILABLE)

FEBRUARY 16, 1990

CLEMSON UNIVERSITY

NONTRADITIONAL ECONOMIC ANALYSIS

(PAPER NOT AVAILABLE)

FEBRUARY 16, 1990

GEORGIA TECH

NONTRADITIONAL ECONOMIC ANALYSIS

NONTRADITIONAL ANALYSIS OF EQUIPMENT ACQUISITION

Dr. B. William Riall, Senior Research Scientist

Georgia Institute of Technology
Georgia Tech Research Institute
Economic Development Division
Apparel Manufacturing Technology Center

February, 1990

Introduction

Georgia Tech has divided efforts to address the quality of decision making in equipment acquisition into two phases. The first phase, completed in November of 1988, had two objectives. The first objective was to assemble and review the literature relating to methods for making decisions on equipment investments and how those methods have been criticized from either theoretical or practical perspectives. The second objective was to conduct a survey of the methods currently used in the apparel industry and to assess whether the criticisms leveled at the traditional methods, as practiced in the apparel industry, were valid.

The second phase of our research effort is directed toward providing software and training that would address the weaknesses found in the apparel companies surveyed. The second phase was recently begun. This paper describes the progress to date and the direction our research is expected to take over the next eight months.

Phase II Objectives and Approach

Our approach to improve the quality of the equipment acquisition decisions incorporates several concepts. First is the need to broaden the scope of the technical aspects of equipment interactions considered. Second, is to integrate the equipment decision with considerations from business areas outside of the production line. Third, is the incorporation of time-path information. Fourth, we wish to impress upon the decision-makers the need to assess what happens if the equipment is not acquired, and provide an analytical structure to accomplish this. Fifth, we will provide alternative methods of compiling and assessing the results.

A new piece of equipment having greater capabilities than what is being replaced often interacts with the existing production system both upstream and downstream of the point in the production line occupied by the equipment. Increases in quality, speed, information, or flexibility can improve, or enable the improvement, of the performance or efficiency of seemingly unrelated production areas. For example, increases in cutter accuracy can improve the efficiency of subsequent sewing operations, or, a unit production system may provide information enabling instant feedback to operators thereby increasing the quality of their work. An analysis of these potential interactions and their likely consequences will be included in the software by tailoring the cost and benefit categories to each type of equipment.

1

While the survey completed in Phase I indicated a generally increasing integration of the equipment decision with strategic planning, it was revealed that in the specific equipment decisions made, short-term production cost reductions were paramount. It therefore appears that there is a need for increasing the non-production related factors in the equipment decision.

Equipment decisions may affect any of the other business areas of the firm. Increased capabilities may enable the pursuit of new markets; better working conditions may reduce absenteeism; evaluating the prospects of the new technology may require changes in cost accounting systems, and implementing new capabilities may be required to meet competitive challenges. Thus, marketing, personnel, finance/accounting, and strategic planning all share in the quality of the equipment acquisition decision-making process. The integration of these interests will be encouraged in several ways. First, projections of markets, market share, and prices will be estimated, both with, and without, the new equipment. Impacts on personnel and their performance will be included in the technical evaluation discussed above, and strategic planning aspects, (not included in the marketing evaluation), will be included in qualitative analysis.

Throughout the quantitative analysis components of the software will be an emphasis on the forecasting nature of the exercise. Hopefully, we can impress upon the decision makers that all information relevant to this decision is a projection into an uncertain future. We will attempt to show that a narrowly focused, payback-criterion decision contains many implicit assumptions about the future that may actually be unlikely. A better approach is to examine all the critical areas of the decision and assess their likely futures explicitly. This would include trends in labor costs, product markets, and material supply. Simultaneously, the impact of the equipment, in all of its costs and benefits, would also be estimated over an expanded time horizon.

If the decision makers can be made to recognize the uncertainties inherent in any forecasting exercise, then the stage is set for a rational consideration of risk. The software will incorporate a risk analysis section related to the probability distributions of the possible outcomes of the critical variables under analysis. Exactly how this will be done is yet to be determined. Hopefully, an calculation of confidence intervals around the expected NPV will be available to the decision-maker. Which variables will receive this additional analysis will be determined

through sensitivity analysis that traces the impact of changes in a single variable. A good feature to have would be the capability to ask what level of a specific variable would cause the decision to change, e.g., cause the NPV to be negative. The extent to which this feature can be incorporated will depend on the final structure of the software. Another feature that is more definite is the capability to develop alternative scenarios where many variables change over the baseline case to correspond to different potential states of nature. For example, a recession would reduce markets, but may also reduce upward pressure on wages and material costs.

The software will be structured to compare two alternatives, i.e., the firm with the equipment, and the firm without it. This will force the decision maker to consider whether or not maintaining the status quo is an option. It will also serve to focus on those aspects of the firm that will change in some fashion with the purchase of the equipment, including items which may normally be considered part of the overhead structure.

While most of the data collected will relate to the quantification of the costs and benefits and the calculation of an expanded NPV, alternative analytical structures will be made available to the decision maker. Specifically, it is anticipated that a simple scoring system and the analytical hierarchy process will be incorporated into the software. It is hoped that the depiction of quantitative analysis as an uncertain forecast will reduce the dependence the decision maker places on "the numbers", in favor of the qualitative assessment techniques.

An important consideration in developing the software will be the role the assessment process has in the ultimate success of the acquisition. Ferreting out all the potential benefits of equipment is the first step toward capturing them. Identifying all of the possible costs is the first step towards reducing them to their minimum. Involving a wider group in the decision process is the first step to establishing broad-based support.

The software will be presented to the industry through a users group involved in the development of the software, and through training sessions expected to last at least three days.

Software Structure

As this phase of the project has begun only recently, this presentation of the anticipated software structure should be regarded as "for discussion." It contains our

3

current thinking, but is constantly being revised as we learn more about the equipment and gain experience with writing this kind of software, how it can be used efficiently, how it can be presented more simply, and how we can convince the decision-makers that it is worth the trouble.

The main menu provides a choice between two data bases. The first contains information about the firm, and the second contains information about the specific project under analysis. The firm information is divided into three subsections. The marketing and strategic factors subsection contains product market information including forecasts. Financial/accounting information has cost information and cost trends. The third firm-level data base subsection relates to production equipment, efficiencies, utilization, and inventories.

The project menu first asks whether a new project is being started, or a revisit is to be made to an old one. If it is a new project, after the name is provided, the user is asked to classify the type of project being considered. Types are first divided into pre assembly (design, marker making, cutting, etc.), assembly, production management (product tracking, etc.), and finishing/storage. These classifications will be refined as the cost and benefit categories are defined for the equipment.

After providing the classification information, the user will be presented with a menu which allows a choice between:

- cost information
- operating conditions, such as utilization rates
- benefits
- type of analysis
- scenario development
- sensitivity analysis
- risk analysis
- analysis results/report generation

The types of analyses to be made available to the user will be an expanded form of NPV, a simple scoring system, and the AHP model.

4

SOFTWARE STRUCTURE

MAIN MENU OPTIONS:

- REVIEW COMPANY PROFILE DATA

- ANALYZE INVESTMENT OPPORTUNITY

  - MARKET AND STRATEGIC FACTORS

  - FINANCIAL AND ACCOUNTING FACTORS

  - PRODUCTION FACTORS

SOFTWARE STRUCTURE

MAIN MENU OPTIONS:

- REVIEW COMPANY PROFILE DATA

- ANALYZE INVESTMENT OPPORTUNITY

  - NEW PROJECT

  - EXISTING PROJECT

SOFTWARE STRUCTURE

MAIN MENU OPTIONS:

- *REVIEW COMPANY PROFILE DATA*

- **ANALYZE INVESTMENT OPPORTUNITY**

  - **NEW PROJECT**

  - *EXISTING PROJECT*

  PRE-ASSEMBLY

  DESIGN

  GRADING

  MARKER MAKING

  SPREADING

  CUTTING

SOFTWARE STRUCTURE

MAIN MENU OPTIONS:

- REVIEW COMPANY PROFILE DATA

- ANALYZE INVESTMENT OPPORTUNITY

  – NEW PROJECT

  – EXISTING PROJECT

  ASSEMBLY

  UPS

  BUNDLE

  MODULAR/FMS

  HYBRID

SOFTWARE STRUCTURE

MAIN MENU OPTIONS:

- *REVIEW COMPANY PROFILE DATA*

- **ANALYZE INVESTMENT OPPORTUNITY**

  - NEW PROJECT

  - *EXISTING PROJECT*

    PRODUCTION MANAGEMENT

    - *TRACKING*

    - *PLANNING*

    - *COORDINATION*

    - *CUT ORDER PLANNING*

SOFTWARE STRUCTURE

MAIN MENU OPTIONS:

- REVIEW COMPANY PROFILE DATA

- ANALYZE INVESTMENT OPPORTUNITY

  -- NEW PROJECT

  -- EXISTING PROJECT

  FINISHING/STORAGE

  FINISHING

  STORAGE

  WAREHOUSING

MARKETING AND STRATEGIC INFORMATION

This data base will contain product price and profitability information on existing and projected markets. It will also contain guidance on how to develop projections. Strategic factors would include competitive challenges, changing market conditions or activity in supplier sectors.

Financial and Accounting information:

This data base would include cost of capital, baseline financial information, depreciation, and tax rate information.

Production Information

This data base would include equipment used, efficiencies, level of utilization, inventory levels, through-put times, and other information significant to the analysis of specific equipment.

COST PROJECTIONS

Categories to vary by equipment under analysis in all cases to cover the initial investment costs and recurring costs over the life of the project.

Operating Conditions

The structure of this data base to depend upon the equipment under analysis and will be a function of both the equipment and the interactions this project is likely to have with other operating areas.

Benefits

The categories of benefits would be specific to the type of equipment under investigation.

Type of Analysis

1. Analytical Hierarchy Process

2. Weighted Scoring

3. Expanded NPV

Scenario development

This section would enable the user to assess the impact

of modifying multiple data simultaneously to corresspond to alternative assumptions about future conditions in markets or costs.

Sensitivity analysis

This section would enable the user to test the sensitivity of the conclusion to the change in a single variable.

Risk Analysis

This section would investigate the range of outcomes attributable to the uncertainty associated with the costs and benefits extimated in the analysis.

Analysis results

The presentation of the results of the analysis would depend upon the type of analysis chosen and the type of equipment under investigation.

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FASHION INSTITUTE OF TECHNOLOGY

NONTRADITIONAL ECONOMIC ANALYSIS

(PAPER NOT AVAILABLE)

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CLEMSON UNIVERSITY

AGV

A USER INTERFACE SYSTEM
FOR
AUTOMATED GUIDED VEHICLES

by

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ABSTRACT

A considerable cost is incurred in today's manufacturing industry in the process of manually moving components between work stations. One possible means of reducing this cost may be found through the use of computer-controllable Automated Guided Vehicles (AGVs). However, development of suitable computer software for the specific requirements of a plant, in a cumbersome, machine-oriented AGV Operational Language, has hindered the widespread use of AGVs. Development of such software is virtually impossible for the typical AGV-user, a non-programmer.

This paper presents a tool that enables a non-programmer to specify an AGV's functions for a dynamic manufacturing plant and automatically generates the required control software. Various approaches considered for developing such a tool are analyzed. Finally an implementation of one approach at the Clemson Apparel Research plant is discussed.

INTRODUCTION

In today's manufacturing industry, a substantial amount of manual effort is being spent on transferring sub-assemblies from work station to work station during the various stages involved in producing a finished product. Even the most advanced plants usually go only to the extent of installing high technology machines to automate the individual phases of the manufacturing process. They normally leave the task of constantly moving components among the work stations to manual labor, incurring a considerable cost.

An Automated Guided Vehicle (AGV) can greatly reduce the manual effort required for transfer of goods within a manufacturing plant. An AGV is basically a remotely controlled vehicle that can perform operations like picking up boxes, carrying them along a pre-defined collection of paths and delivering the boxes to specified locations. The AGV is instructed by a host computer which broadcasts packets of instructions through a Radio Frequency (RF) transmitter. Inquiries can be made by the host to the AGV regarding its status and location.

A computer program is required to periodically determine the next set of instructions to be transmitted to the AGV, based upon the following main factors:

1. *Status of the work stations:* The status of a work station determines the type of service to be rendered by the AGV.
   (e.g.) "Ready for picking up of goods"
          "Waiting for delivery of goods"
   This status can be conveyed to the computer by some external communication device like a lazer gun, door bell, bar code reader, etc.

2. *Status of the AGV:* This includes the current physical location of the AGV within the plant and the current load on the AGV. These can be obtained by the host computer by inquiring to the AGV.

Thus, control of an AGV requires an AGV Control Program (AGV-CP) which can "listen to" the work stations regarding their status, inquire to the AGV about its location and other important information, and command the AGV to perform a clearly defined set of operations. The AGV-CP must constantly perform these tasks throughout the time when the plant is in production.

Generally speaking, manufacturing personnel, who use AGVs to assist in material movement within plants, are not programmers. They need a facility to assist in specifying the AGV's

functionality in their plants and to convert these specifications to a computer program which transmits the AGV's operational language.

This paper presents a User Interface System (UIS) - an interface between a non-programmer and the AGV - that accepts a definition of the functional specifications of the AGV from a non-programmer and performs transformation of these specifications to a computer program which instructs the AGV accordingly. This interface system is, in effect, a tool that automates development of a suitable AGV-CP starting from a non-programmer's specifications.

For the purposes of illustration, an apparel manufacturing plant is described, since UIS was developed and demonstrated in an apparel plant, viz. the Clemson Apparel Research plant (CAR), in Pendleton, South Carolina. The AGV used was a Litton Series 800 Automated Guided Vehicle, donated by IBM to CAR.

In what follows, the concepts and working principles of UIS are discussed. Section 1 presents an overview of the AGV and its complex communication procedure, which was a motivation for development of this tool. Section 2 identifies the required characteristics of the UIS, through a step-by-step process, from a fundamental view point. Section 3 proposes possible approaches to development of an interface system. Section 4 describes, in detail, the working procedure of UIS and finally, Section 5 concludes the paper.

For the reader's convenience, a list of acronyms used in this paper is given below:

AGV	-	Automated Guided Vehicle.
AGV-CP	-	Automated Guided Vehicle Control Program to control the AGV.
CAR	-	Clemson Apparel Research plant where the interface system was developed and demonstrated.
HLL	-	High Level Language.
TM	-	Transfer Mechanism of the AGV that transfers boxes.
UIS	-	User Interface System, the title of this paper.
UOL	-	User Operations List, a list of AGV operations built by the user for each LOCATION CODE during the specification entry.
USF	-	User Specification File, a text file containing user's specifications in the form of HLL statements.
USU	-	User Specification Utility.
VSC	-	Vehicle System Controller for communicating with the AGV.

2

SECTION 1.
AN OVERVIEW OF AGV AND THE OPERATIONAL LANGUAGE

1.1 Features of the Litton 800 AGV:

The Litton 800 AGV consists of a Guidance System, a Power Train, and a Control System. The control system incorporates a microprocessor giving the vehicle decision making capabilities and the ability to follow commands from a Vehicle System Controller (VSC), otherwise known as a Host Computer. The vehicle receives its commands and responds with status by communicating with the VSC via a UHF radio data communications link. The Guidance System receives information from the Scanning Sensor Head sub-system and controls the steering servo sub-system. The Power Train is a servo controlled motor that drives the front wheel of the tricycle AGV.

The basic features of the AGV include the following:

1. A Multi-Load Transport with a Transfer Mechanism (TM) that loads and unloads up to four boxes. The TM has an elevator that can transfer boxes to external devices at various height positions.

2. An Addressable Transmitter allows devices external to the vehicle to be selectively activated and deactivated. These could be door openers, annunciators or other devices.

The guide path for the AGV consists of a line of fluorescent tape (masking tape works fine) that is used to form a route for the AGV to follow. The path can have right or left branches to alternate AGV's routes. Codes are marked along the guide path to identify vehicle location. These codes will be referred to as LOCATION CODEs in the following sections. These codes are necessary to keep track of the vehicle's location and to designate where a particular command is to be executed.

The AGV executes lists of commands keyed to LOCATION CODEs as the codes are read along the guide path (Deferred Mode). In addition, commands can be implemented immediately upon receipt by the vehicle (Immediate Mode).

1.2 The Communications Protocol:

The Communications Protocol between the AGV and the VSC is initiated by a radio transmitting a message frame containing either the commands for the vehicle to perform or an inquiry request of vehicle status. The message frame has the following format:

Header Field, m1, m2, ..., m20, Trailer Field.

The Header and Trailer bytes contain items like opening and closing flags, address of the vehicle, hand-shaking information, etc. The Data Field (m1, ..., m20) is a sequence of 1 to 20 message blocks each of which is made of 9 bytes. A message block is basically one vehicle command. Its component bytes have the following significance:

> Byte 1 : Immediate/Deferred mode indicator
> Byte 2 : LOCATION CODE (For Deferred Commands)
> Byte 3 : Command Code
> Byte 4 : Delay Specification byte
> Byte 5 : Implement Delay Value
> Byte 6 : Termination parameter
> Byte 7 : Auxiliary parameter
> Byte 8 : 1st command parameter
> Byte 9 : 2nd command parameter

1.3 Translating a User Requirement to an AGV Message:

Constructing the AGV messages for every operation to be performed by AGV is quite tedious. To illustrate this, an example is presented below:

To perform a Transfer-A-Box operation from the current position of the AGV, the message to be used is,

Byte-1	Byte-2	Byte-3	Byte-4	Byte-5	Byte-6	Byte-7	Byte-8	Byte-9
1a	00	0b	01	14	00	00	11	10

The preceding are hexadecimal bytes whose individual bits carry valuable information to the AGV. For instance, the significance of byte-8's bits are,

bit6	- Nature of the transfer
bit5	- Whether the transfer is a load or unload

bit4   - Which side of the AGV to perform the transfer

bit3 through bit0   - The number of boxes to be transferred.

Prior to the transfer operation, the AGV must be physically routed to the desired location and prepared for the transfer by several other messages, the construction of which will require equally tedious procedures.

Thus, the conventional approach of developing a custom-made program for AGVs for the specific requirements of a plant layout would involve considerable amounts of tedium and programming effort and is error-prone. Besides, modification to this program, when changes or enhancements are required, will also be difficult and error-prone.

The purpose of the UIS presented in this paper is to provide a better human interface to the AGV. A non-programmer will easily be able to accomplish the task of defining the AGV's functions as well as incorporating future enhancements.

SECTION 2.
CHARACTERISTICS OF THE UIS

The UIS has two major components to communicate the user's needs to the AGV:

1. An interactive utility that interfaces with the user to obtain the specifications of AGV's activities. This utility is referred to as the User Specification Utility (USU).

2. A suitable AGV-CP, produced by the USU, to interface with the AGV.

To automate creation of the AGV-CP, a model for such a control program must be developed. This model will provide insight into the facilities to be incorporated into the USU. The following sections identify these requirements:

2.1 Analysis of a typical manufacturing plant

A typical manufacturing plant has several work stations, each acting on one phase of the entire manufacturing process. For example, in a shirt manufacturing plant, the individual work stations may perform operations like stitching pockets, buttons, sleeves, cufflinks, assembling the sub-components, producing the finished product, packaging the product, etc.

The state of each work station will be constantly changing. The work station may be waiting for its input components, ready for its products to be picked up, or even both

5

simultaneously. Each of these states may require service from the AGV. The commands to be executed by the AGV in order to accomplish this service will depend on the AGV's current location within the plant, since these commands must include the ones for taking the appropriate branches along the guide path and skipping the intermediate LOCATION CODEs.

2.2 Methods for Identifying AGV's functions:

Considering the two main factors, namely the state of the plant and the location of the AGV, the AGV's operations in a dynamic manufacturing plant can be identified in two possible formats:

1. Use the state of the plant as a major reference, and for each value of the state, identify the AGV operations for each location where the AGV can possibly be positioned at that time.

2. Use the AGV's location as the major reference and define the operations based on the various states of the plant.

The former approach is more difficult to visualize since the major reference, viz. the state of the plant, is a collection of numerous combinations of the individual work station's states. On the other hand, in the latter approach one has a clearly defined major reference, the set of LOCATION CODEs. Operations to be performed at the current location can be identified for all states of the particular work station adjacent to the current location. Once the adjacent work station is serviced, the next location to be serviced by the AGV can be determined based on the states of upcoming work stations.

2.3 AGV's Role in an Example Plant Set up:

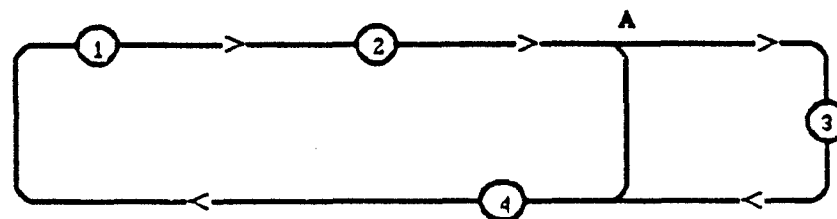An example is presented below to illustrate the second approach presented in section 2.2:

Figure 1. Layout of work stations of a plant

Consider the plant layout shown in Figure 1. The following important aspects form the basis of the AGV's functions in this plant:

- Work stations at LOCATION CODE 2 and LOCATION CODE 3 (referred to as work station 2 and work station 3) manufacture products which require pick up by the AGV when they are ready. The work stations have some communication device to inform the host computer of their status.

- LOCATION CODE 4 denotes the warehouse where the products must be delivered.

- LOCATION CODE 1 is where the AGV normally stays when there is nothing to be done. This acts as a starting point for the AGV.

- Work station 2 is of higher priority than work station 3, meaning, if both are ready at the same time, the former is serviced first; work station 3 gets service only when work station 2 demands no service.

With these parameters, the AGV's functions can be identified as shown in Figure 2.

In case the AGV is currently stopped at LOCATION CODE 1
   if LOC2_IS_READY or LOC3_IS_READY
      proceed to LOCATION CODE 2 and stop

In case AGV is currently stopped at LOCATION CODE 2
   if LOC2_IS_READY
      pick up goods
      proceed to LOCATION CODE 4 and stop
   else
      proceed to LOCATION CODE 3 and stop

In case AGV is currently stopped at LOCATION CODE 3
      pick up goods
      proceed to LOCATION CODE 4 and stop

In case AGV is currently stopped at LOCATION CODE 4
      deliver goods
      proceed to LOCATION CODE 1 and stop

Figure 2. AGV's functions in the example plant

LOC2_IS_READY and LOC3_IS_READY denote the corresponding work stations being ready for service. Please note that, since the LOCATION CODE is the major reference for AGV's next set of instructions, each of these sets must be terminated with an instruction that stops the AGV at a new LOCATION CODE.

2.4 Characteristics of AGV-CP:

In order to control the AGV for the above operations the required AGV-CP must include the instructions shown in Figure 3:

In a repetitive loop, do the following:

- *Inquire to the AGV to see if it is stopped at any particular location.*

- *Check for occurrences of any asynchronous interrupts to set conditions like LOC2_IS_READY, to TRUE*

- *If the AGV has stopped, then*

> *If the current LOCATION CODE = 1*
> > *if LOC2_IS_READY or LOC3_IS_READY*
> > > *Set the AGV in motion*
> > > *Ask AGV to stop when LOCATION CODE 2 is encountered*

> *If the current LOCATION CODE = 2*
> > *if LOC2_IS_READY*
> > > *Position the AGV's TM to appropriate height*
> > > *Activate a stationary device to feed a box*
> > > *Perform Load-A-Box operation*
> > > *Set the AGV in motion*
> > > *Make the AGV take the Right Branch at point A*
> > > *Ask the AGV to stop when LOCATION CODE 4 is encountered*
> > > *Set the condition LOC2_IS_READY to FALSE*
> > *else*
> > > *Set the AGV in motion*
> > > *Make the AGV take the Left Branch at point A*
> > > *Ask the AGV to stop when LOCATION CODE 3 is encountered*

> *If the current LOCATION CODE = 3*
> > *Position AGV's TM to the appropriate height*
> > *Activate a stationary device to feed a box*
> > *Perform Load-A-Box operation*
> > *Set the AGV in motion*
> > *Ask the AGV to stop when LOCATION CODE 4 is encountered*
> > *Set the condition LOC3_IS_READY to FALSE*

> *If the current LOCATION CODE = 4*
> > *Position the AGV's TM to appropriate height*
> > *Activate a stationary device to accept a box*
> > *Perform Unload-A-Box operation*
> > *Set the AGV in motion*
> > *Ask the AGV to stop when LOCATION CODE 1 is encountered*

Figure 3. AGV-CP for the example plant

This is a typical sequence of instructions to be executed by the AGV-CP. The following general characteristics of the AGV-CP are now clear. The AGV-CP must,

1. Remain in a major loop while the plant is in operation.

2. Obtain the state of the work stations and the AGV. If the AGV is currently in motion, pause for a while and get back to the beginning of the loop.

3. Go through a test of the AGV's current LOCATION CODE. This can be implemented through *Case Statements* in a High Level Language (HLL) like Pascal.

4. Whenever the AGV gets to a new LOCATION CODE and stops, transmit a collection of commands based on the state of the work stations. These commands will eventually route and stop the AGV at a new LOCATION CODE.

5. Three types of statements are essential:
   - Function calls for constructing AGV message frames for the required commands.
     (e.g.) Set_the_AGV_in_motion
   - Statements for testing conditions. (e.g.) IF LOC2_IS_READY
   - Statements for setting conditions. (e.g.) LOC2_IS_READY := FALSE

2.5   Required Features of the USU:

The general format of the AGV-CP and the type of instructions required imply that the USU must include the following essential features:

- Accept the list of LOCATION CODEs where the AGV must stop to perform operations and, for each LOCATION CODE, accept the operations to be performed.

- Allow the user to specify any of the AGV operations and accept the associated parameters. For example, if *Take-A-Left-Branch* operation is to be specified, the position of the branch in the guide path with reference to either a LOCATION CODE or the current position of the AGV is a necessary parameter.

- Enable the user to include conditional performance of operations. This means a condition like *If LOC2_IS_READY* must be accepted by the USU and checked during run time by the AGV-CP. Consequently, inputting the associated *Else* and *End-If* must also be possible.

9

- Setting conditions at one location which might affect the operations at another location must be possible. In the above example, *Set LOC2_IS_READY to FALSE* was essential, or work station 3 would never have received service.

The USU, after accepting the input from the user, must output the specifications in some format that will form the core of the AGV-CP. With these basic guidelines, some possible approaches to an interface system are discussed in Section 3.

SECTION 3.
POSSIBLE APPROACHES TO AN INTERFACE SYSTEM

The general characteristics of the user's needs, the USU and the AGV-CP have been analyzed in section 2. The next step is to determine a method to save the user's input and utilize it in a suitable AGV-CP to accomplish the necessary functions. There are two possible approaches for this:

3.1 The Interpretive Approach:

The USU can accept the user's specifications and output a file of data that can be interpreted by a suitable interpreter at run time (Figure 4). This approach requires development of an interpreter with the following features:

- The method of constructing AGV messages from user's parameter data may be incorporated into the interpreter.

- For conditional execution of instructions, a format for specifying the conditions must be established and the interpreter must test the conditions and take appropriate actions at run time.

- For Setting conditions, again, a suitable syntax must be established and the interpreter must be able to assign a value to a variable at run time.
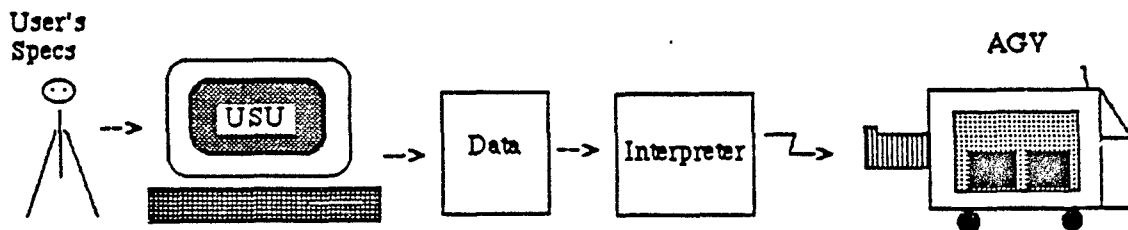

Figure 4. The interpretive approach.

10

Developing an interpreter involves a considerable amount of programming effort.
Incorporating possible enhancements to the interface system (e.g. *While* statements), will
also be tedious. A compiled approach solves these problems.

3.2 The Compiled Approach:

In this approach the USU outputs a file containing statements in a HLL, which can form the
core of a target program (AGV-CP) written in the same language (Figure 5). The AGV-CP
thus formed can be compiled and executed to serve the required purpose. This approach
avoids the necessity of developing an interpreter and instead makes use of existing HLL
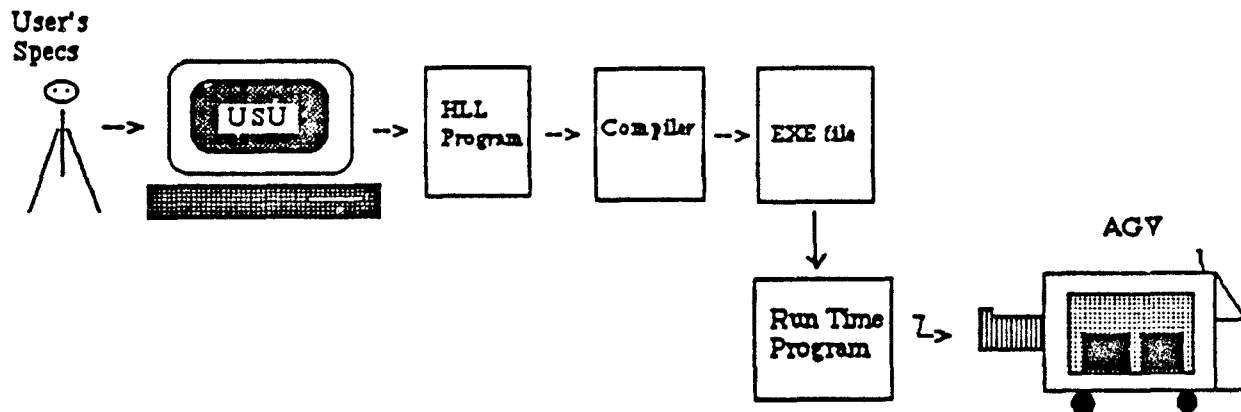compilers.

Figure 5. The compiled approach.

For each AGV operation in the user's specification, the USU can output a HLL function call.
For example if FORTRAN IV is the language of the AGV-CP, then for each AGV operation,
the USU can produce a statement,

$$CALL\ TRANSMIT\ (B1, B2, B3, B4, B5, B6, B7, B8, B9)$$

where $B1, ..., B9$ are constants that have been calculated by the USU, based on the user
input. *TRANSMIT* can be a sub-program that merely transmits the given 9 bytes. For *Test
Condition* and *Set Condition* operations the USU can produce the equivalent *if* statements
and *assignment* statements. In addition to being easier to implement and maintain, the
compiled approach produced a program whose performance is far superior to the interpretive
approach.

11

SECTION 4.
WORKING PROCEDURE OF THE UIS

The compiled approach was adopted for the UIS and Pascal was chosen to be the language of the AGV-CP. In UIS, the two major components identified in section 2 work as follows:

1. The USU accepts the user's input and generates a User Specification File (USF), which is a text file containing Pascal statements.

2. A model AGV-CP program, written in Pascal, has statements for all the house-keeping operations like polling the AGV, etc, and includes the USF with a *{$I ..}* compiler directive to form the complete AGV-CP.

4.1 Working Procedure of the USU:

The USU goes through two important phases, The User Input Phase and The Code Generation Phase.

4.1.1 The User Input Phase:

In this phase the user specifies the operations to be performed at various LOCATION CODEs, along with their required parameters, using a User Specification Input Screen (Figure 6.)

The Available Operations List has all the possible AGV operations as well as provision for specifying *If/Else/End-If* statements and *Set-Condition* statements. The purpose of this screen is to build the User Operations List (UOL) from the Available Operations List for a given LOCATION CODE. The Editing Mode Menu provides all the necessary editing features like Append, Modify, Delete, Insert, etc for building the UOL.

Whenever a particular element in UOL is being edited, a Parameter Input Window (PIW) specific to the particular operation, appears (Figure 7). For example if the *Set Speed* operation is chosen, then the PIW accepts the value of the speed, the implementation delay, the duration of the implementation, etc.

LOCATION CODE: 5

Editing Mode	Available Operations		User Operations
Append Insert Delete Modify View Indent Quit	Set Speed Find Marker Left Edge Follow Position TM Reset TM Fault Suspend Inhibit Proximity Det Steer Angle Else Condition Set Condition	Stop AGV Right Edge Follow Do Nothing Transfer Box Cancel Resume Addressable Xmitter If Condition End-If	

Figure 6. The User Specification Input Screen

LOCATION CODE: 5

Editing Mode	Available Operations		User Operations
Append > Insert Delete Modify View	> Set Speed Find Marker Left Edge Follow Position TM	Stop AGV Right Edge Follow Do Nothing Transfer Box	> Set Speed Stop AGV

Set Speed

Immediate Mode/Deferred Mode........: I
Reference Location........................: 99
Delay Specification......................: G
Amount of Delay..........................: 0
Duration of Execution...................: 0
New Speed Value..........................: 31

Figure 7. The Parameter Input Window for *Set Speed* Operation

13

While the PIWs for all AGV operations are similar, the ones for the *If Condition* and *Set Condition* options are different. The *If Condition* option requires that the user enter a Boolean expression conforming to Pascal syntax that must be TRUE for execution of subsequent statements. The *Set Condition* option asks the user to enter a variable name and the value/expression to be assigned to the variable.

Several data items are declared in the model AGV-CP for use in the *If Condition* and *Set Condition* PIWs, and more may be added as needs arise. Presently some preliminary validations are made to the Boolean expression and assignment statements entered by the user.

4.1.2   The Code Generation Phase:

After UOLs for all the desired LOCATION CODEs are built, the USU enters the Code Generation Phase where it generates the USF. The contents of USF are shown in Figure 8.

```
Procedure Process_Loc_Operations;
begin
    Case Loc_Code of

        L1:   begin
              stmt 1.1
              stmt 1.2
              .
              .
              stmt 1.1'
              end {L1}

        L2:   begin
              stmt 2.1
              stmt 2.2
              .
              .
              stmt 2.2'
              end {L2}
          .
          .
        Ln:   begin
              stmt n.1
              stmt n.2
              .
              .
              stmt n.n'
              end {Ln}

    end; {case}
end; {Procedure Process_Loc_Operations}
```

Figure 8. The User Specification File

In the USF, $L1, L2, ..., Ln$ are the LOCATION CODEs entered by the user. The UOL of each LOCATION CODE Li is translated to a block of Pascal statements, *<Begin stmt i.1; ...; stmt i.i'; End>* , each of which represents one operation in the UOL.

The rules for formulating these statements are as follows:

1. Every AGV operation is translated to a Pascal function call,
   formcmd (b1, b2, b3, b4, b5, b6, b7, b8, b9);
   where $b1,...,b9$ are AGV instruction bytes computed by the USU based on the operation and the user's parameters.

2. An *If Condition* is translated to
   If <Boolean> then begin
   where *<Boolean>* is the Boolean expression entered by the user for the *If Condition* option.

3. An *Else* option forms the lines
   env.
   else begin
   in the USF.

4. An *End_If* option forms the line
   end;
   in the USF.

5. The Set Condition is outputted in the USF as,
   <variable> := <value>;
   where *<variable>* and *<value>* are the variable name and the value entered by the user.

The procedure *Process_Loc_Operations* will be invoked by the AGV-CP during run time.

The user requirements outlined in Figure 3 were entered using the USU. The corresponding USF generated by the USU is shown in Figure 9. A one-to-one correspondence may be observed between the instructions in Figure 3 and the statements in Figure 9. A comparison of these two figures helps understand the rules for USF generation.

```
Procedure Process_Loc_Operations;

Begin
   Case Loc_Code of

      1: begin
         If (r2 or r3) then begin
            formcmd ($1a, $00, $85, $00, $00, $00, $00, $1f, $00);     {Set Speed}
            formcmd ($02, $02, $ff, $00, $00, $00, $00, $00, $00);     {Stop AGV}
         end;
         end; {1}
      2: begin
         If (r2) then begin
            formcmd ($1a, $00, $84, $00, $00, $00, $00, $dc, $00);     {Posn TM}
            formcmd ($1a, $00, $01, $01, $10, $14, $00, $84, $00);     {Xmitter}
            formcmd ($1a, $00, $0b, $01, $1e, $00, $00, $01, $00);     {Xfer Box }
            formcmd ($1a, $00, $85, $01, $40, $00, $00, $1f, $00);     {Set Speed}
            formcmd ($1a, $00, $83, $00, $05, $0a, $00, $00, $00);     {Rt Edge Fl}
            formcmd ($02, $04, $ff, $00, $00, $00, $00, $00, $00);     {Stop AGV}
            r2 := FALSE;
         end
         else begin
            formcmd ($1a, $00, $85, $00, $00, $00, $00, $1f, $00);     {Set Speed}
            formcmd ($1a, $00, $82, $00, $05, $0a, $00, $00, $00);     {Lf Edge Fl}
            formcmd ($02, $03, $96, $00, $00, $00, $0C, $00, $00);     {Stop AGV}
         end;
         end; {2}
      3: begin
            formcmd ($1a, $00, $84, $00, $00, $00, $00, $bb, $00);     {Posn TM}
            formcmd ($1a, $00, $01, $01, $10, $14, $00, $82, $00);     {Xmitter}
            formcmd ($1a, $00, $0b, $01, $1e, $00, $00, $01, $00);     {Xfer Box }
            formcmd ($1a, $00, $85, $01, $40, $00, $00, $1f, $00);     {Set Speed}
            formcmd ($02, $04, $ff, $00, $00, $00, $00, $00, $00);     {Stop AGV}
            r3 := FALSE;
         end; {3}
      4: begin
            formcmd ($1a, $00, $84, $00, $00, $00, $00, $0a, $01);     {Posn TM}
            formcmd ($1a, $00, $01, $01, $10, $14, $00, $81, $00);     {Xmitter}
            formcmd ($1a, $00, $0b, $01, $1e, $00, $00, $21, $00);     {Xfer Box }
            formcmd ($1a, $00, $85, $01, $40, $00, $00, $1f, $00);     {Set Speed}
            formcmd ($02, $01, $ff, $00, $00, $00, $00, $00, $00);     {Stop AGV}
         end; {4}

   end; {case}
end; {Process_Loc_Operations}
```

Figure 9.   USF for a test plant set up

In Figure 9, r2 and r3 are Boolean variables declared in the model AGV-CP and represent work station 2 and work station 3, respectively, being ready. Each *formcmd* procedure call includes the hexadecimal bytes calculated by the USU based on the AGV instruction and the data obtained in the PIWs.

16

4.2 Model AGV-CP:

The model AGV-CP has the following structure:

While Plant_is_in_operation do begin

    Inquire_AGV; {To get the current LOCATION CODE and status of the AGV}

    If an External_Interrupt_has_Occurred
       Set_the_Work_Station_Status_Variables;

    If the AGV_is_Stopped then begin
       Form_Header_Part_of_the_AGV_Message_Packet;
       Process_Loc_Operations; {The procedure in the USF}
       Form_Trailer_Part_of_the_AGV_Message_Packet;
       Transmit_the_Packet_to_the_AGV;
       Wait_until_the_AGV_Starts_Moving;
    end;{If}

end;{While}

The primary components of the model AGV-CP are explained below:

- Inquiring of the AGV assigns the last read LOCATION CODE to the global variable *Loc_Code*.

- AGV being in motion would imply that it is still in the process of executing the previous message packet received, since every message packet is terminated with a *Stop-at-a-new-location* message. Thus, only when AGV has stopped will the AGV-CP send the next message packet.

- The *Case* statements in the *Process_Loc_Operations* procedure pass control to the appropriate block of the current *Loc_Code* where the necessary message packet for the particular *Loc_Code* is constructed through *formcmd* procedure calls. *formcmd* is a simple procedure in the model AGV-CP that appends the given nine bytes to the AGV message packet.

17

- On insertion of the header and trailer parts, the message packet becomes a valid message frame acceptable to the AGV, and is then transmitted to the AGV.

- The AGV-CP idles until the AGV starts moving from the current location, or transmission of the same message packet may be repeated at the current location. Once the AGV starts moving, the above cycle repeats.

- Meanwhile, the AGV-CP also maintains the variables indicating work station status values through external communications from the work stations.

SECTION 5.
CONCLUSIONS

This paper presented a User Interface tool for specification of an AGV's function in a manufacturing plant. Even a non-programmer can easily interact with this tool since it provides descriptive explanations for the parameters as they are entered, together with a context-sensitive help screen. Through use of this tool, manufacturing specialists can concentrate on the tasks they are best trained for, those involving planning and direct manufacturing. The programming tasks associated with AGV operations are entirely eliminated. This tool avoids the necessity for learning the machine-oriented AGV Operational Language. Thus, an enormous amount of tedium, confusion and errors in developing and maintaining a suitable AGV-CP is avoided.

This tool provides a fundamental framework for the automation of AGV-CP creation. The tool at present outputs the AGV operations in the form of Pascal code; however, it could be easily modified to output code in any target language. The set of statements supported by the tool can be increased as new requirements are identified.

18

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FEBRUARY 16, 1990

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

APPAREL PRODUCT EXCHANGE STANDARDS

Academic Apparel Research Conference on
Advanced Apparel Manufacturing Technology

Session on Computer Integrated Manufacturing
February 16, 1990

The Apparel Product Data Exchange Specification

Dr. Ted Hopp

Leader, Machine Intelligence Group
National Institute of Standards and Technology

NIST

Contents of Presentation

- The need for product data exchange standards

- How PDES works

- Extending PDES to apparel

NIST

The Need for Product Data Exchange Standards

Enable computer integration of the entire product life cycle to:

— Produce better products
— Produce them faster
— Produce them at lower cost
— Respond quickly to changing market demands

Without standards...   communication is the problem

With standards...   it's the solution

What Does PDES Specify?

- Data elements that define a product

- Measurable data (e.g., features, tolerances, materials)

- Knowledge of processes

NIST

APDES Will Create Opportunities

APDES Will	APDES Will **NOT**
Allow communication of pattern data	Specify standard patterns
Establish terminology for sizes	Define standard sizes
Allow grading rules to be described	Define the grading rules themselves
Allow processes to be defined	Establish standard processes
Provide a standard language for technological data	Impose specific apparel technology

CHARACTERISTICS OF PRODUCT DATA

LIFE CYCLE DATA TYPES

- Market
- Requirements
- Decision
- Acquisition
- Definition
- Production
- Test
- Operation
- Support
- Disposal
- History

Before product exists

After product exists

Physical
(Shape or material)

Functional
(What it does, what happens to it)

Process or Programmatic
(Cost, schedule, nomenclature, etc.)

CATEGORY
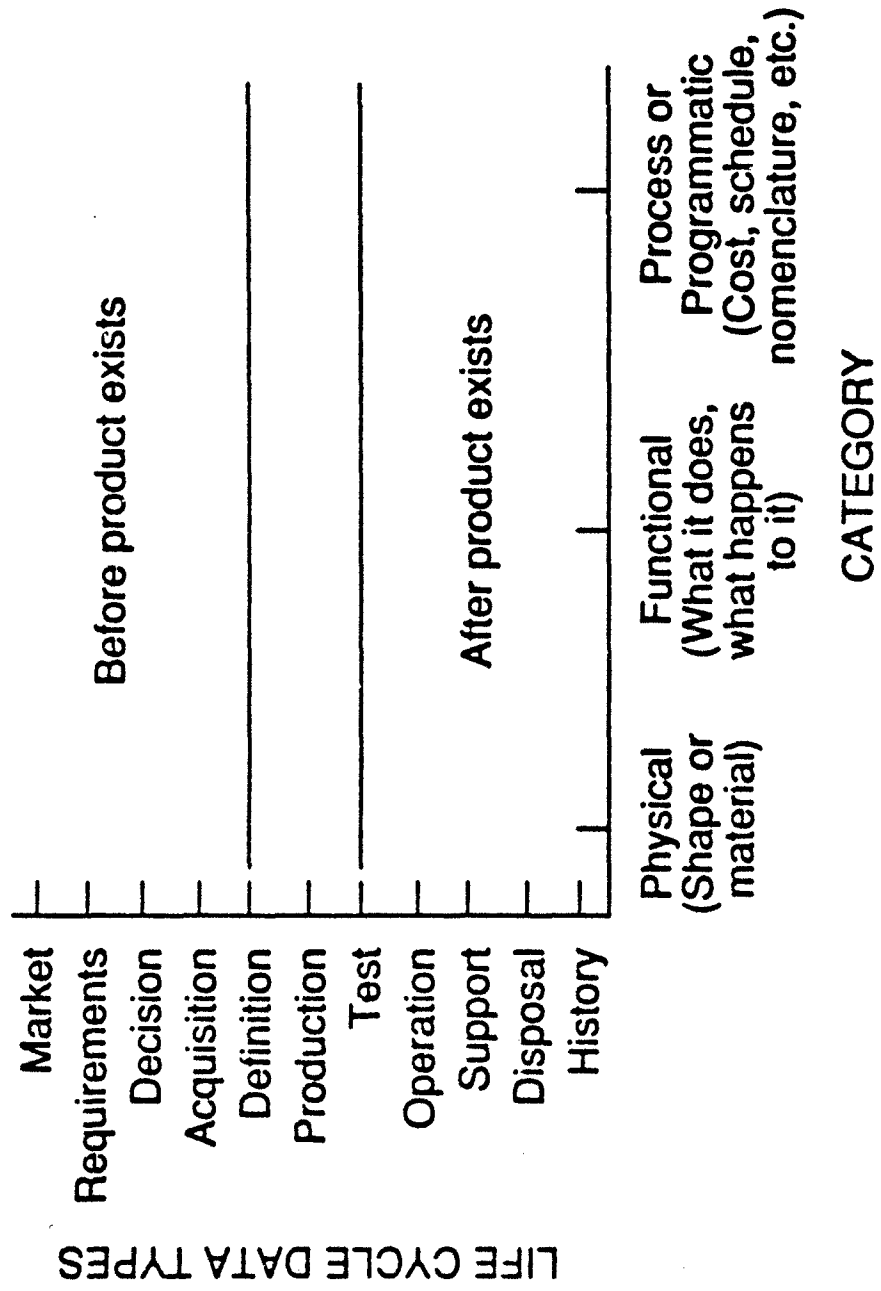
Pattern Data Exchange Using External Files

System
1 → PostProcessor → External File → PreProcessor → System 2
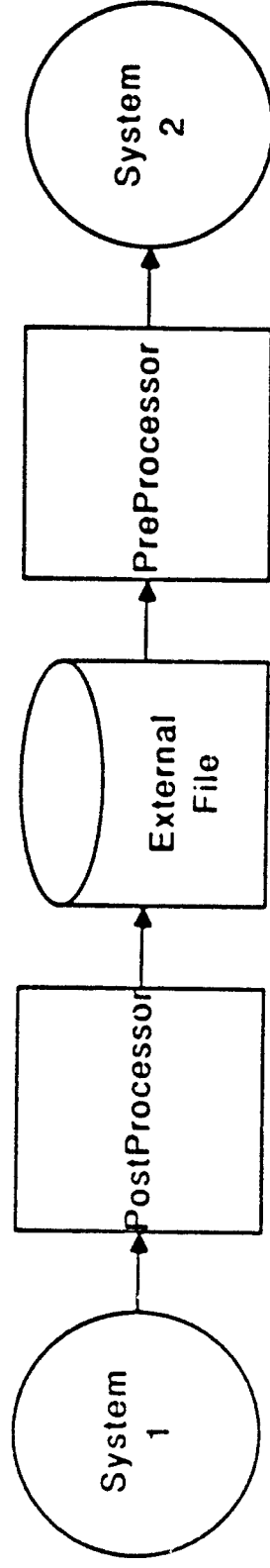
Attributes of External File Formats

Neutral ↕ System-dependent

Public ↕ Proprietary

General Purpose ↕ Specialized

File Exchange Between Systems
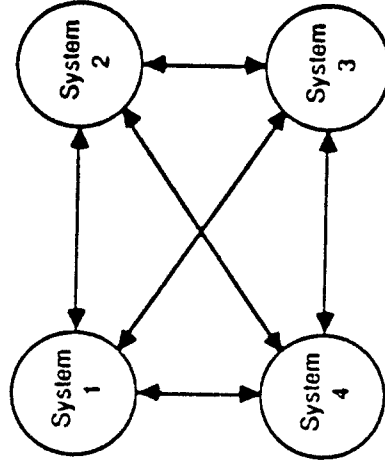
System-dependent Formats:
N(N-1) translators
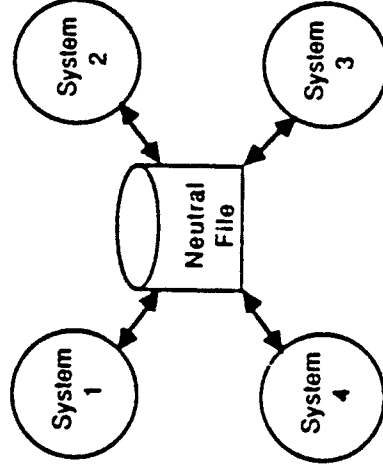
Neutral Format:
2N translators

Product Data Integrates the Apparel Lifecycle

Pattern Making

Grading

Marking

Design

Shared Product Database

Textile Design

Sales

Sewing

Cutting
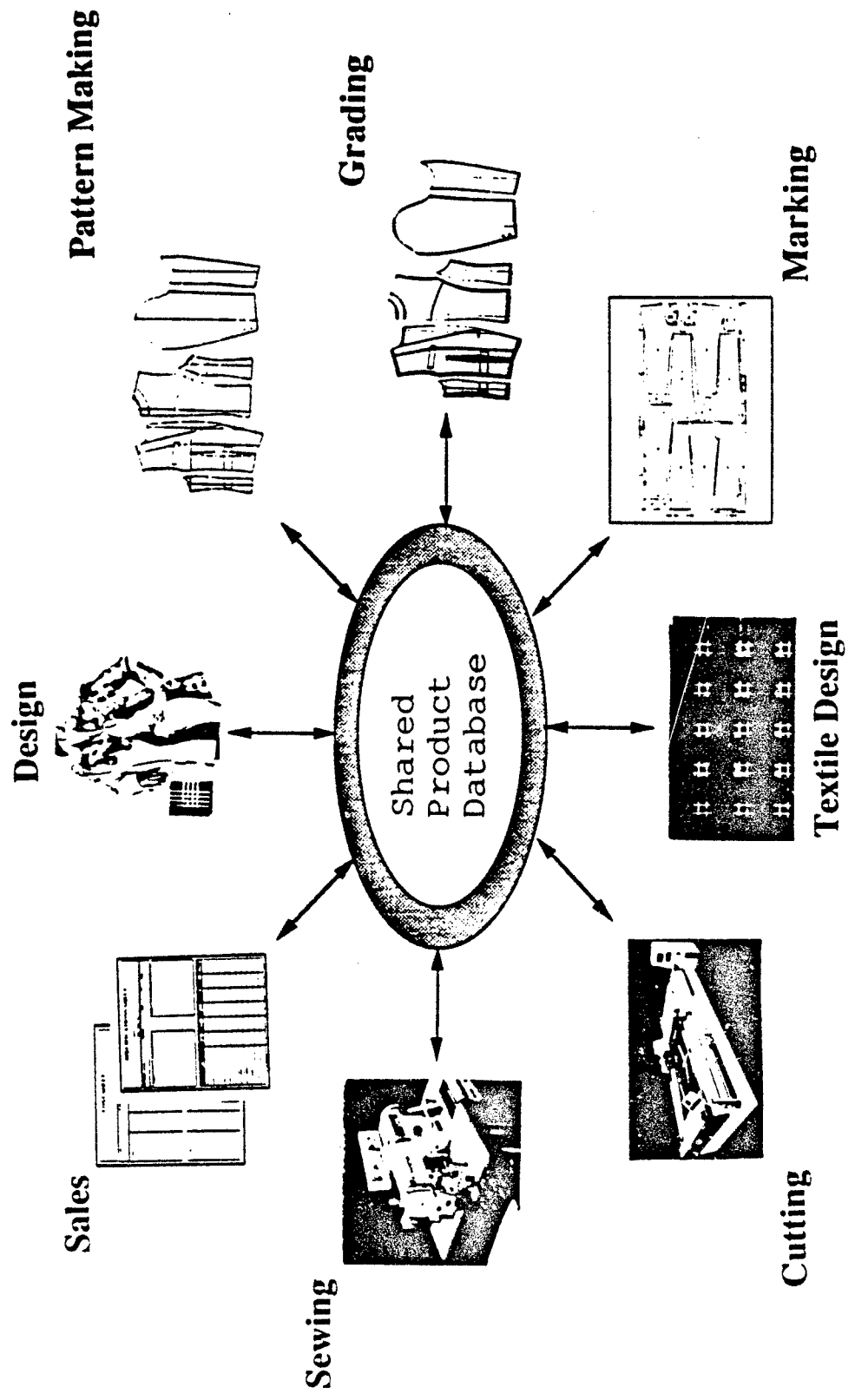
The Three-Layer Architecture of PDES
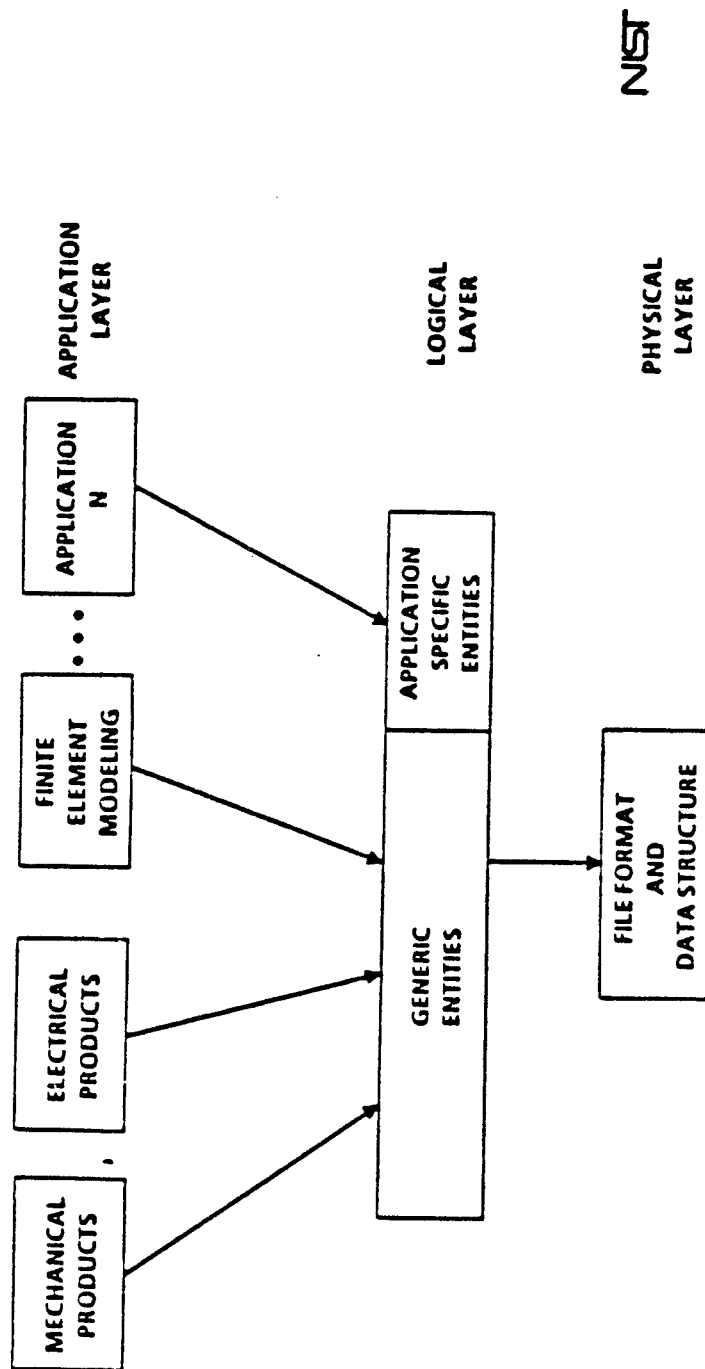
PDES is Flexible

Mechanical
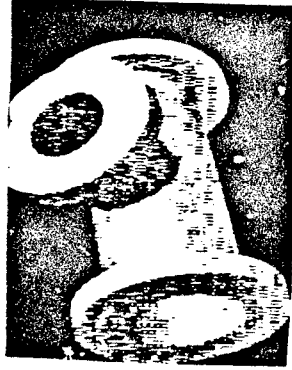
Electrical
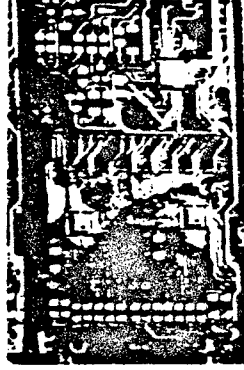
Architectural
Engineering
& Construction

Apparel
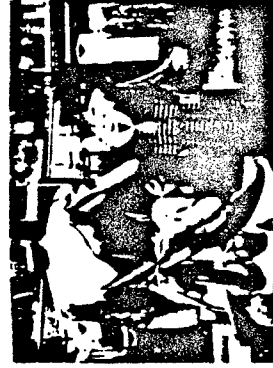
PDES is More than a Standard
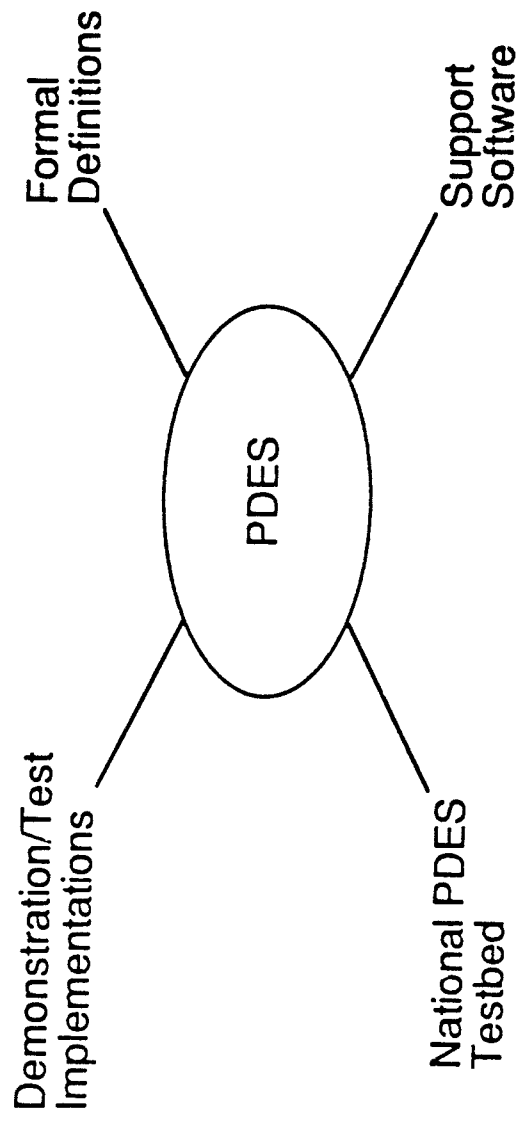
How STEP/PDES Entities Are Defined

Name

Number

Definition (text)

EXPRESS Definitions

Attribute Definitions

Constraint Definitions

Propositions

IDEF1X Definition

NIST

Example of Attribute Definition

Tolerance

The numeric range that defines the allowable deviation

of the location dimension

Example of Constraint Definition

If the dimension is linear, then no path is specified,

if non-linear, then a path must be specified

Example of Propositions

A Location Dimension may be a curvi-linear measurement

between shape elements

Example of IDEF1X Definition
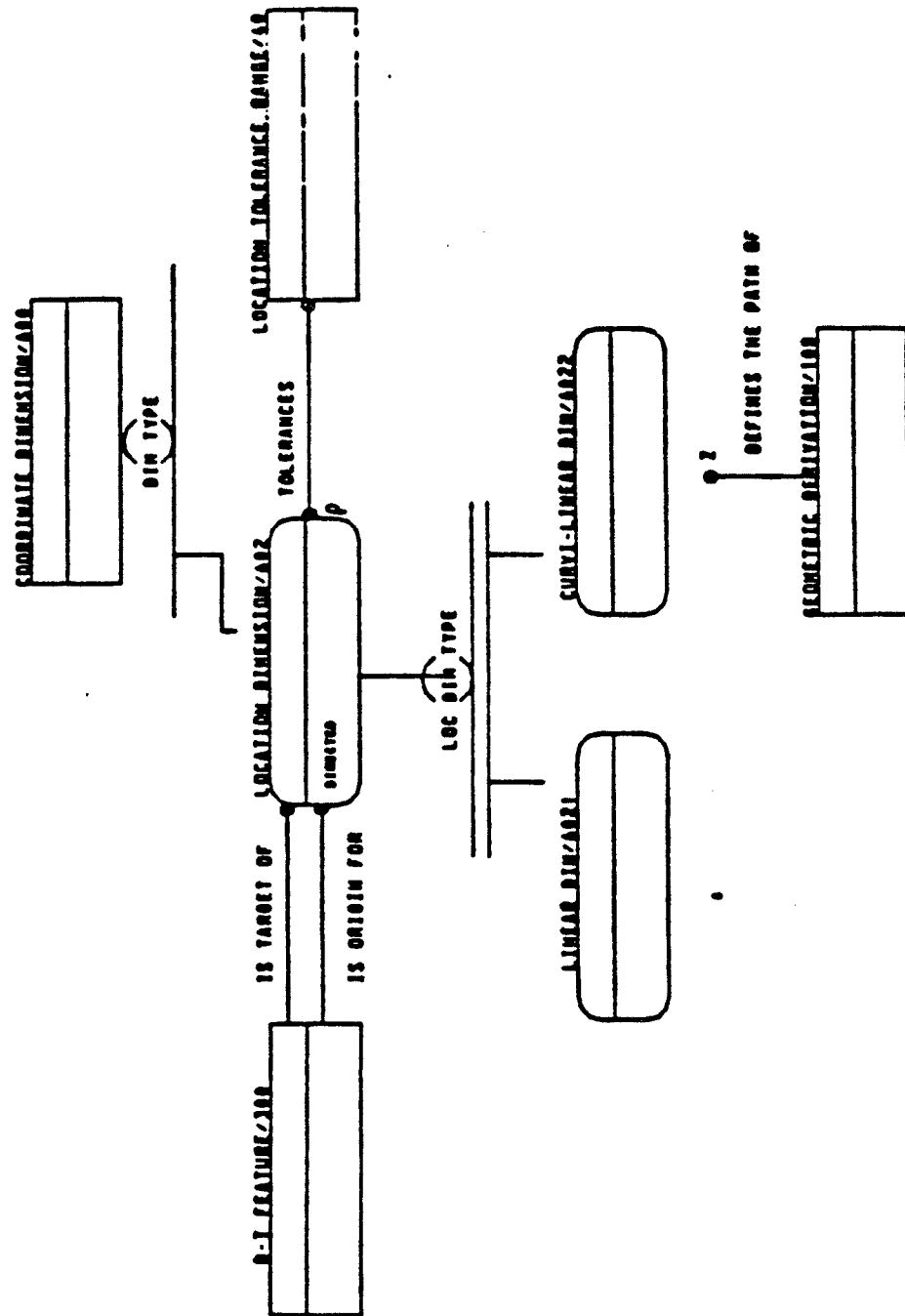
Example of EXPRESS Definition

EXPRESS Definition

ENTITY pattern_line SUBTYPE OF (pattern_piece);

type   : line_type;

line_points : LIST [1:#] OF pattern_point;

END_ENTITY;

TYPE line_type = ENUMERATION OF

  (drill_hole, notch, grade_line, grain_line, annotation_line);

END_TYPE;

Architecture for Schema - Independent Applications
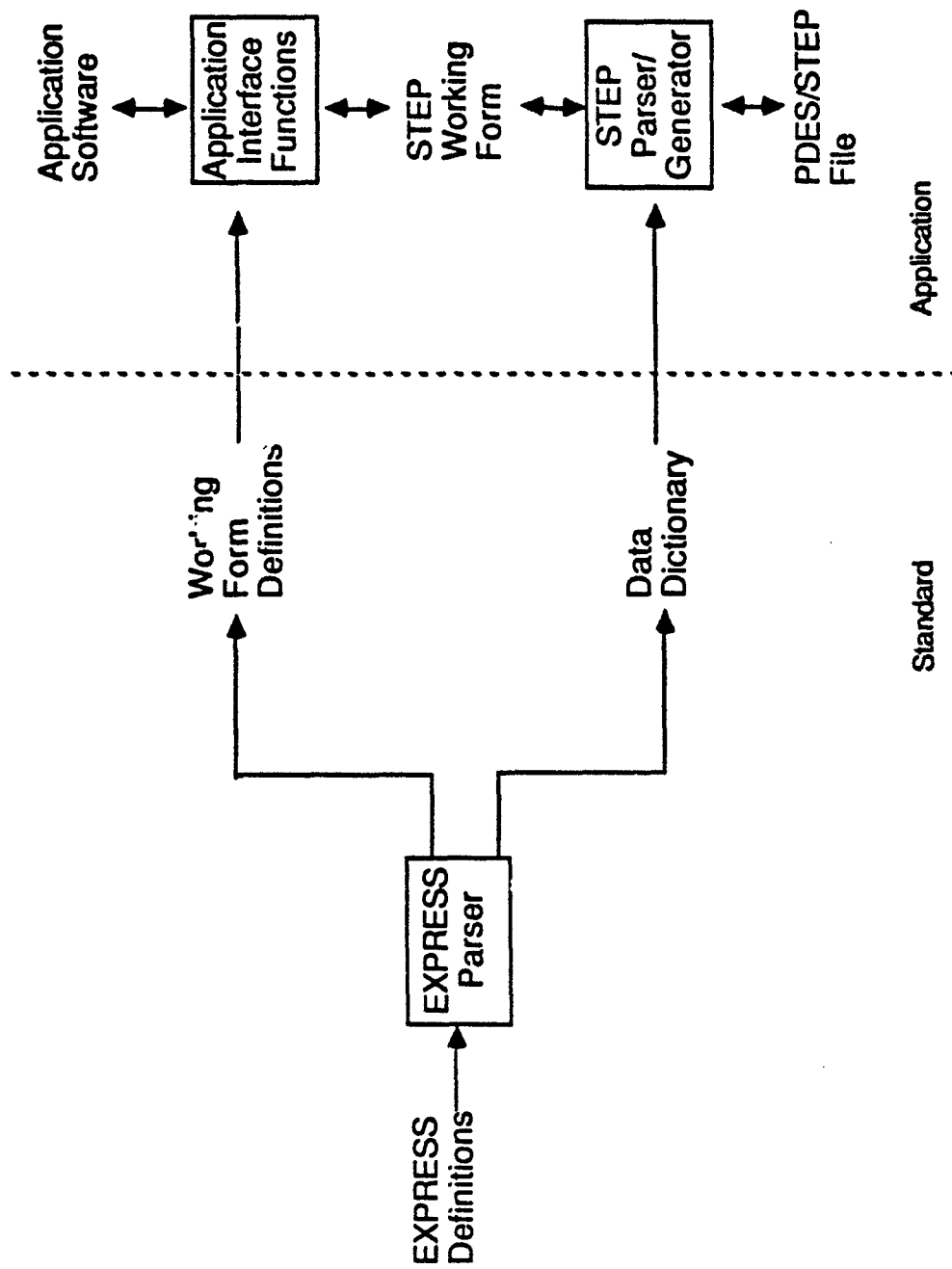
Development Begins With Requirements

— 2-D Patterns
— Grading data
— Markers
— Configurations (styles)
— Process definition data
— Material (fibers, textiles)
— Fasteners

• • •

NIST

Apparel Data Requirements

Information Contained on Pieces

Design Data

- Cutting Information
- Sewing Information
- Grading Information
- Style Information
- Marking Information
- Sketching/Design Information
- Spec Sheet
- Cost Sheet
- Related Data

Data Items

- Darts
- Pleats
- Style Lines
- Bands
- Yokes
- Shirring/Gathers Shirring Ratios
- Collars
- Sleeves
- Trims
- Cuffs
- Facings
- Closures
- Pockets

Computer Information

Point Types
- dart - pleat - notch

Beginning & Ending of Lines

Line Types
- grade reference - stripe/plaid
- grain lines - annotation
- style lines - Xpoint lines
- internal cutouts - drill holes lines
- alternate grade reference lines
- user defined lines - neck, armhole, etc

Corners

Curved Intersections

Seam Allowance
- sew and cut lines
- even and uneven

Original and Current Piece Orientation

Special Types of Pieces
- mirrored - folded
- flipped - rotated
- scored

Line to Line Relationships

Timeline for APDES Development

Formalize requirements

Develop Express definitions

Implement PDES translators
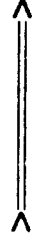
Build prototype systems

FEBRUARY 16, 1990

CLEMSON UNIVERSITY

ELECTRONIC BULLETIN BOARD

The

Apparel Manufacturing Information System (AMIS)

for the

Apparel Advanced Manufacturing Technology

(AAMTD)

Demonstration Project

Dr. Harold Grossman
Department of Computer Science
Clemson University
Clemson, S.C. 29634-1906
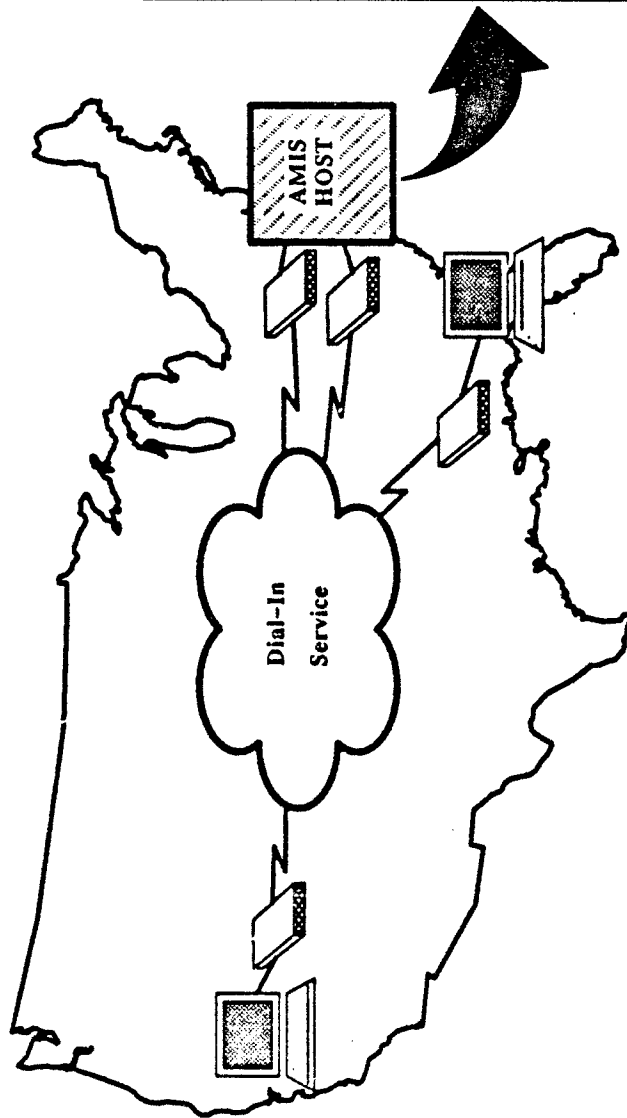
AMIS

The Apparel Manufacturing Information System

SERVICES

- Electronic Mail
- Bulletin Boards
- Databases
- File Repository
- Forum
- Specialized Software for Project Subgroups

AMIS HOST

Dial-In Service

AMIS

CLEMSON UNIVERSITY

Access to Information Distribution System

AMIS HOST

USER

Direct Connection

2400 baud
MNP Error-Correcting Modems

Error Free

Noise Sensitive

Regular Telephone Lines

300, 1200 and/or 2400 baud regular modem

Terminal or PC Running Communications Software

USER

USER
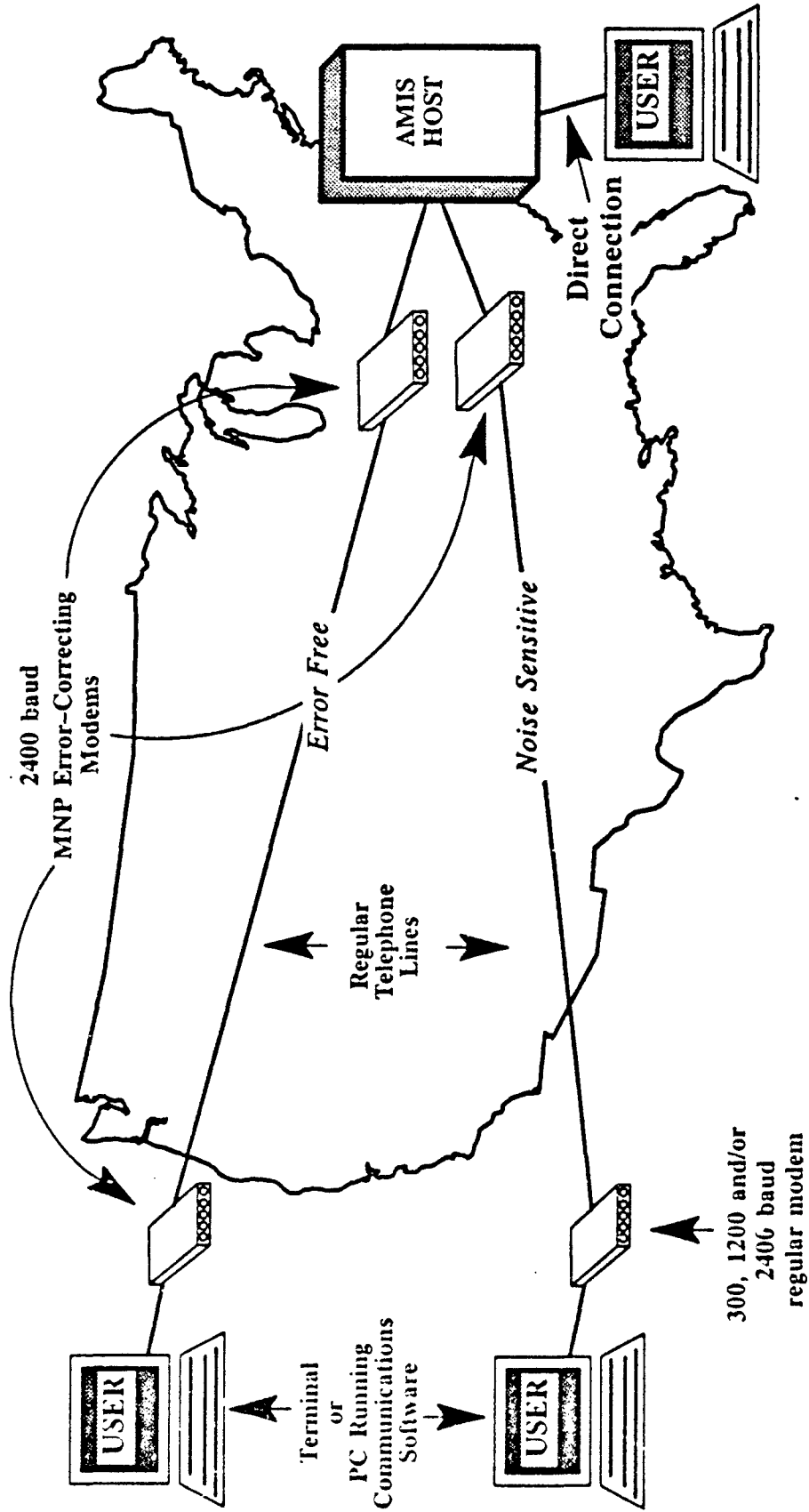
AMIS

```
AMIS login: harold
Password:
You  have mail.
```

```
HELP ALT F10    | VT102    | FDX |  2400 N81 | LOG CLOSED | PRINT OFF | ON-LINE

-----------------------------------------------------------------------------

                             Welcome to the

                Apparel Manufacturing Information Service

                                  at

                            Clemson University

NOTE:
        - The communications parameters are 8 bit, no parity, one stop bit.

        - Line wrap should be turned ON.

        - VT100 emulation required.
```

COMMAND: **Mail** Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
        Fileservices Transfers Listuser(s) Changepassword Quit Help
    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold   2/10/1990 11:28   XENIX

MAIL >Enter Mailbox or Bulletin Board Name -- or return for inbox: **inbox**

Enter options
/usr/acct/harold   2/10/1990 11:28   XENIX

Mailbox is 'inbox' with 4 messages [Version 3.2-c]

```
1<-   Apr 26 harold        Bibliographic create script
2     May 4  amis          Re: Bibliographic create script
3     Jan 23 harold        bill peay
4     Jan 23 harold        exiting editor
```

M)ail send, D)elete, R)eply, G)roup reply, F)orward, U)ndelete
N)ext message, S)ave to mailbox, C)hange mailbox, Q)uit
? - HELP
<return> - read current message   ! - list current message
<number> - set message number   / - pattern search

Mail : ?

H E L P   S C R E E N
---+----------------------------------

MAIL COMMANDS	POSITIONING COMMANDS
c Change current mail box	<n> Set current message to n
d Delete current message	= Set current message to 1
f Forward message to specified user	* Set current message to last
g Group (all recipients) reply to	message
message.	j Increment current message by 1
m Mail to arbitrary user(s)	<down-arrow> "
r Reply to current message	k Decrement current message by 1
s Save message to specified mailbox	<up-arrow> "
q Quit the mail system	+ Next page of headers
u Undelete current message	- Previous page of headers

+----------------------------------

<return> Read current message	MISCELLANEOUS COMMANDS
! List current message without	? This screen of information
pausing at end of screen.	h Toggle msg. header suppression
n Read next message	t Display time and date
	ctrl-L Rewrite Screen
/ Search mailbox from current	ctrl-Z Exit without modification
message for given string	

Please type <space> to return:

```
1<-    Apr 26 harold          Bibliographic create script
2      May 4  amis            Re: Bibliographic create script
3      Jan 23 harold          bill peay
4      Jan 23 harold          exiting editor
```

```
        M)ail send, D)elete, R)eply, G)roup reply, F)orward, U)ndelete
            N)ext message, S)ave to mailbox, C)hange mailbox, Q)uit
                              ? - HELP
        <return> - read current message      ! - list current message
        <number> - set message number        / - pattern search
```

Mail : **<return>**

From harold Wed Apr 26 11:34:28 1989
To: amis harold
Subject: Bibliographic create script
Date: Wed Apr 26 11:34:27 1989

From: +++!harold (Dr. Harold C. Grossman - Clemson University)
Cc: harold
X-Mailer: msg [version 3.2-c]

Dave,

I have placed in /usr/local/bin and script called BIBupdate.sh which may be
executed by first cd /usr/local/bin and then ./BIBupdate.sh You are prompted
for a title, a file name and then a list of key words. The key words must be
entered one at a time. The keyword prompting is terminated with a period on a
line by itself. This script creates a file called /usr/etc/bib.dir which I
will use to generate the menus etc. Can you please put several files in
/usr/etc and also the corresponding entries into the bib
directory(BIBupdate.sh)

thanks

Please press <space> to return:

```
COMMAND: Mail Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
         Fileservices Transfers Listuser(s) Changepassword Quit Help
     >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold                                    2/10/1990  11:29    XENIX

-----------------------------------------------------------------------------
```

```
SENDMAIL  Enter User ID(s) or Bulletin Board Name: madison
To: madison
Subject: demonstration message
Copies To: harold
```

You are about to enter the editor. Simply type your message.
From within the editor enter:

                ESC ?   For Help Menu,
                ESC H   For Help Summary Screen,
                ESC E   To Exit Editor.

Do you want to perform an ASCII file upload of a message that you have
previously prepared on your PC before entering the editor (y/n)? n

------------------------ --
LYRIX /tmp/snd.27156   PL66   #1   9:7
L.......T.......T.......T.......T.......T.......T.......T.......T.......T....R
Wayne,

This is the AMIS word processing/editor system. Notice that I do not have to
be concerned about where a line ends unlike most other electronic mail
systems. I can do most of the typical word processing activities such as
deletion and insertion. There is also an extensive help facility that can be
entered in the middle of typing a message.

harold
(End Of File)---

```
-------< Exit Commands >-------------|----------< Cursor Move >-----------
Exit and save         Esc e         | Left                Left Arrow
Quit No Save          Esc q         | Right               Right Arrow
Write no exit         Esc w         | Up                   Up Arrow
Save to file          Esc x         | Down                Down Arrow
----------< Delete >-----------------| Go Left             Esc Left Arrow

Delete character      Ctrl-c        | Go Right            Esc RightArrow

Delete word           Ctrl-w        | Go Up                Esc Up Arrow
Delete line           Ctrl-x        | Go Down             Esc Down Arrow

Delete blank lines    Esc db        | Top of screen       Ctrl-t
                                    | Top of file         Esc t
Delete right          Esc dr        | Bottom of screen    Ctrl-b
Delete left           Esc dl        | Bottom of file      Esc b

Erase previous char   DEL or RUB    | Go to Page          Esc p
----------< Insert >-----------------| Next word           Ctrl-n
Insert space          Ctrl-e        | Previous word       Ctrl-p
Open line             Ctrl-o        |
Add blank lines       Esc al        | Scroll Down         Ctrl-d
Enter insert mode     Esc i         | Scroll Up           Ctrl-u
Start Overstrike Mode Esc o         |
(stop insert mode)                  |
-------< Miscellaneous >-------------|-----------< Cut & Paste >-----------
          Press <Return> to continue or <CTL>-a to abandon.
```

```
Terminate command     Ctrl-v        | Mark-top block      Esc (b
Abort program         Ctrl-\        | Mark-top serial     Esc (s
Escape to menu         Esc !        | Mark-top line        Esc (l
Redraw  screen         Esc v        | Mark-bottom Blank    Esc )b
Spell                 Esc $         | Mark-bottom Leave    Esc )l
Restore Text          Ctrl-r        | Mark-bottom Remove   Esc )r
  (Undo)                            | Paste-text Overlay   Esc *o
Do Again              Ctrl-A        | Paste-text Insert    Esc *i
Help                  Esc h         | Paste-text Elbow     Esc *e
--------< Text Format >-------------| Paste-text File      Esc *f
Reformat paragraph    Ctrl-f p      |
Reformat document     Ctrl-f        |-------< Merging Files >---------------
Convert lower case    Esc kl        | Merge overlay       Esc mo
Convert upper case    Esc ku        | Merge insert         Esc mi
Center Line           Esc c         |
Start print effect    Esc <         |-------< Text Search >-----------------
End print effect      Esc >         | Find String         Esc f
Show  print effect     Esc @        |    (Search)
Line split            Esc l         | Find Next Occurrence  Esc n
Join Line             Esc j         | Global find and replace Esc g
Footnote              Esc +         |
Automatic Number      Esc #         |
------< Alternate Modes >-----------|-----------< Dot Commands >----------
          Press <Return> to continue or <CTL>-a to abandon.
```

```
Enter mode                 Esc {       ¦ Page Length                    .PLn
Quit mode                  Esc }       ¦ Heading Text next n lines      .HEn
                                       ¦ Footing Text next n lines      .FOn
         Mode Numbers                  ¦ Heading Margin                 .HMn
Auto-Tab                      t        ¦ Footing Margin                 .FMn
Hyphenation                   h        ¦ Forced Page Break              .PA
Insert                        i        ¦ Conditional Break if < n lines .PMn
                                       ¦ Line Spacing of n lines        .SPn
---------------< Rulers >--------------¦ Set Page Numbers To n          .PNn
 Recall Ruler              Esc r       ¦ Stop Global Reformat           .JN
 Store Ruler               Esc s       ¦ Restart Global Reformat        .JY
                                       ¦ Send Code Now         .SN [code]
                                       ¦ Send Code Top         .ST [code]
------< Valid Ruler Characters >-------¦ Send Code Bottom      .SB [code]
R     Right Margin, Ragged             ¦ Merge file at print time       .ME
J     Right Margin, Justified          ¦ Remark line                    .RE
L     Left  Margin                     ¦ Footnote Space                 .NSn
T     Tab Stop      C  Center          ¦ Footnote Margin                .NMn
.     Space         H  Hang            ¦ Footnote Number Reset          .NRn
I     Indent        #  Decimal Tab     ¦ Widow/Orphan (# of lines)      .WOn
                                       ¦ Section Head format    .SH format
                                       ¦ Basic List format      .BL format
                                       ¦ Figure List format     .FL format
          Press <Return> to continue or <CTL>-a to abandon.


----------------------------------------------------------------------


                                       ¦ Independent List format  .IL format
                                       ¦ Reset Section Number           .RS
                                       ¦ Reset Basic list               .RB
                                       ¦ Reset Figure List              .RF
                                       ¦ Reset Independent List         .RI
                                       ¦
----------------------------------------------------------------------



                         Press <Return> to continue

    Are you  sure you  want to send this? (y/n)   y
```

```
COMMAND: Mail Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
         Fileservices Transfers Listuser(s) Changepassword Quit Help
    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold                                  MAIL    2/10/1990  11:33   XENIX


---------------------------------------------------------------------------------




BULLETINBOARD >Enter Bulletin Board Name -- or return for list: <return>


Enter options
/usr/acct/harold                                  MAIL    2/10/1990  11:33   XENIX
```

```
BULLETIN BOARDS
  car
  dlasrp
  events
  inbox
  newprods


Enter name of bulletin board: events
```

Mailbox is '/usr/spool/mail/events' with 12 messages [Version 3.2-c]

```
 1<-    Jun 16 amis        BREAKING TRADITION
 2      Sep 26 amis        AAMA - Other Seminars this FALL
 3      Sep 26 amis        AAMA - New  Publications
 4      Oct 3  amis        NET PRESENT VALUE MADE USER-FRIENDLY
 5      Nov 10 amis        THE LANDS' END CONNECTION - ED HILL
 6      Dec 25 amis        New  Text Books
 7      Dec 25 amis        NC State Univ, Calender of events
 8      Jan 23 amis        Inter. Exhibition for Text. Innov Feb 6-8 19
 9      Jan 23 amis        USIFI Outlook '90 Feb 15-16 1990
10      Feb 6  amis        WORLD TEXTILE CALENDER

         M)ail send, D)elete, R)eply, G)roup reply, F)orward, U)ndelete
            N)ext message, S)ave to mailbox, C)hange mailbox, Q)uit
                              ? - HELP
         <return> - read current message      ! - list current message
         <number> - set message number        / - pattern search

Mail :
```

```
Mailbox is '/usr/spool/mail/events' with 12 messages [Version 3.2-c]

    1    Jun 16 amis          BREAKING TRADITION
    2    Sep 26 amis          AAMA - Other Seminars this FALL
    3    Sep 26 amis          AAMA - New  Publications
    4    Oct 3  amis          NET PRESENT VALUE MADE USER-FRIENDLY
    5    Nov 10 amis          THE LANDS' END CONNECTION - ED HILL
    6    Dec 25 amis          New  Text Books
    7    Dec 25 amis          NC State Univ, Calender of events
    8    Jan 23 amis          Inter. Exhibition for Text. Innov Feb 6-8 19
    9    Jan 23 amis          USIFI Outlook '90 Feb 15-16 1990
   10<-  Feb 6  amis          WORLD TEXTILE CALENDER

       M)ail send, D)elete, R)eply, G)roup reply, F)orward, U)ndelete
          N)ext message, S)ave to mailbox, C)hange mailbox, Q)uit
                          ? - HELP
       <return> - read current message     ! - list current message
       <number> - set message number       / - pattern search

Mail : 10




--------------------------------------------------------------------------------


From amis Tue Feb  6 16:03:56 1990
To: events
Subject: WORLD TEXTILE CALENDER
Date: Tue Feb  6 16:03:55 1990

From: +++!amis (Apparel Manufacturing Info Service - Clemson Apparel Research)
X-Mailer: msg [version 3.2-c]


                WORLD  TEXTILE  CALENDER

Feb 4-8 :

18th Australian Polymer symposium, Bendigo, Victoria, Australia. Sponsored by
the Polymer Division of the Australian Chemical Institute. Contact Dr. J.D
Wells, bendigo, College of Advanced Education, Bendigo, Victoria 3550,
Australia

Feb 7-14 :

Eighth International Wool Textile Research Conference, Christchurch, New

Press <space> to continue:                              78 lines left
```

```
COMMAND: Mail Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
         Fileservices Transfers Listuser(s) Changepassword Quit Help
    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold                              MAIL    2/10/1990  11:35    XENIX


--------------------------------------------------------------------------------
```

```
INQUIREBOXES: Listmailboxes Quicklist Removemailbox

    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold                              MAIL    2/10/1990  11:35    XENIX
```

```
MAILBOX NAME          TYPE                MESSAGES
car                   BulletinBoard          41
dlasrp                BulletinBoard           4
events                BulletinBoard          12
inbox                 BulletinBoard           0
newprods              BulletinBoard          29
themeday              Regular                 1
```

```
COMMAND: Mail Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
         Fileservices Transfers Listuser(s) Changepassword Quit Help
     >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold                              MAIL    2/10/1990  11:35   XENIX

------------------------------------------------------------------------------


           Welcome to the AMIS Bibliography Search System


Enter a key word or Q to quit:  spin


           AMIS Bibliography Search for 'spin'


   1.  AUTOMATIC TAGGER
```

```
Selection 1 of 1
Enter a selection number, a command, Q to quit or ? for help:  1
```

AUTOMATIC   TAGGER

        JOS GALKIN CORP. announces the GAP 1000 Auto-Tagger. The GAP 1000 Auto-Tagger
        is completely automatic. The operator handles only the garment, either folded
        or open.

        The section of garment to be tagged is placed over a projecting anvil. A
        paddle switch is located on the right side, allowing the operator to trip the
        machine with the back of the hand, without changing the natural garment
        grasping position.

        The Auto-Tagger anvil automatically raises the garment area to be tagged and
        clamps it to the bottom of the tag delivery shelf. A tag is automatically
        simultaneously fed out from the tag hopper.

        The needle automatically passes through the hole in the tag and through the
        garment.

        A barb is inserted through the tag and garment and the needle is retracted.

        The anvil drops and the operator removes the tagged garment.

        [(1¦26)Screen Pause] Enter command, Q to quit or ? for help: ?

        Display Commands are:
                Q - quit displaying
                N - display next piece of information
                F - go one screen forward in displaying the information
                P - display the previous piece of information
                B - go one screen backwards in displaying the information
                H - displays this message
                ? - displays this message
                    help, Help, ? all do the same thing
                G <#> - go to a specific line number in the information
                <#> - go to a specific line number in the information

        [(1¦26)Screen Pause] Enter command, Q to quit or ? for help: Q

        Enter a key word or Q to Quit? test

1. DEVELOPMENT PROCESS FOR DESIGN/GRADING/MARKING
2. FLAW DETECTION SYSTEM
3. SOFTWARE FOR QUALITY CONTROL
4. FLEX AND FOLD TESTER
5. CONTROL SYSTEM FOR INDUCTION AND DC MOTOR
6. NEW BRUSHLESS D.C MOTOR
7. LAUNDRY APPAREL PRESS
8. MODULAR CONTROL SYSTEM FOR INDUCTION & DC MOTOR
9. STONE WASHING PRODUCT

Selection 1 of 9
Enter a selection number, a command, Q to quit or ? for help: 9

STONE   WASHING   PRODUCT

TEXTILE CARE, DIVISION OF ECOLAB INC.,ST.PAUL, MINNESOTA announces the
introduction of Stone-eze, a new age stonewashing product designed to create
all the softness, comfort and highlighting previously done by pumice stones
and harsh chemicals. After extensive testing in research and development
Stone-eze has been introduced to the textile market as a free-flowing powder.

Pre-packaged in 1 lb.portion-control packettes, Stone-eze allows the
manufacturer or contract washer greater productivity by up to 35% per load
while producing controlled quality every time. With as little as 1-lb of
Stone-eze, one can wash as many as 150 pairs of jeans per load. Because
Stone-eze contains no harsh or corrosive chemicals, the product is safe to
use and easy to handle.

Specially formulated for cotton and denim fashions, Stone-eze also works on
the industry's newest twist fabrics. In tests, experts could see no difference
between Stone-eze and rock-washed garments. And the new fashion effects
produced by Stone-eze create a softer fabric and controlled highlighting on
seams and other raised areas on the garment.

REF: Textile care, Division of Ecolab inc. St.Paul Minnesota 55102.

[(1|24)Screen Pause] Enter command, Q to quit or ? for help: Q

Enter a key word or Q to quit: q

COMMAND: Mail Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
         Fileservices Transfers Listuser(s) Changepassword Quit Help
     >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold   MAIL   2/10/1990 11:38   XENIX

```
FILESERVICES: Listfiles Erasefile Movefile Viewfile
             Newdirectory Changedirectory Deletedirectory Quit
    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold                            MAIL ' 2/11/1990  11:03   XENIX

---------------------------------------------------------------------------


Fileservices Listfiles
total 16
-rw-r--r--   1 root      root        6048 Nov 21 12:47 menu.def
-rw-r--r--   1 root      root         533 Sep  7 08:31 vt100b
-rw-r--r--   1 harold    100          609 Sep 16 21:19 {xD!UGk{sy{~rl

COMMAND: Mail Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
        Fileservices Transfers Listuser(s) Changepassword Quit Help
    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold                            MAIL    2/11/1990  11:03   XENIX
```

TRANSFERS: **Upload** Download Quit

TRANSFERS UPLOAD   To: **madison**   Filename: **pcplus.dir**
                   Description: **demo of file upload**
Enter options

           K E R M I T   F I L E   U P L O A D

Kermit will be used to upload file pcplus.dir from your PC to the
directory of user madison.

Mail messages will also be sent to each user notifying
him or her of the receipt of your file pcplus.dir.

Do you wish to continue with the upload (y/n)?**yy**

Kermit upload now being initiated. Enter the Kermit send facility in
your communication's package.

Kermit upload complete.

The file is being placed in the requested user directory.

File /usr/acct/madison/pcplus.dir successfully created for user madison.

Enter a description of the file you sent on the following page. The
description will be mailed to the recipients of the file.

You are about to enter the editor. Simply type your message.
From within the editor enter:

              ESC ?   For Help Menu,
              ESC H   For Help Summary Screen,
              ESC E   To Exit Editor.

Do you want to perform an ASCII file upload of a message that you have
previously prepared on your PC before entering the editor (y/n)? **y**

LYRIX /tmp/REPOS.27484

Wayne,

This is a demonstration of the binary file upload capability. This capability
would allow users to share databases, spreadsheets, word processor files,
graphics or anything that can be represented in a file. The file transfer
system is NOT dependent on specific equipment in the sense that MACs or PCs
can use the transfer capability. One just needs to remember that files
created for the MAC cannot probably be run or used on the PC and vice versa.

harold

TRANSFERS: Upload **Download** Quit

TRANSFERS DOWNLOAD   Filename: **menu.def**

          K E R M I T   F I L E   D O W N L O A D

Kermit will be used to download file menu.def to your PC into the
current DOS directory. The file's name will be retained.

Do you wish to continue with the download (y/n)?yy

Kermit download now being initiated. Enter the Kermit download
facility in your communication's package.

Kermit download complete.

COMMAND: Mail Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
         Fileservices Transfers **Listuser(s)** Changepassword Quit Help
      >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold   MAIL   2/11/1990 11:16   XENIX

LISTUSER(S) Optional Search Pattern: ma

```
grossman    Dr. Harold Grossman - Clemson
madison     Dr. Wayne Madison - Clemson
dev         Krishnamachari Devarajan - Clemson
seaman      Jason Seaman - Clemson
demo        Dr. Harold Grossman - Clemson
mmartin     Mary R. Martin - Anderson College, Anderson, SC
jthomas     Jennifer A. Thomas - American Apparel Manufacturers Association
harold      Dr. Harold C. Grossman - Clemson University
sdharma     Satish Dharmaraj - Clemson University
gbarrett    Gilbert A. Barrett, Jr - Facemate Corp. Chicopee, MA
rmarion     Robert Marion - The Spartan Company, Jackson, MS
togorman    Tom OGorman - Grenwood Mills, New  York, NY
bmoore      Bruce Moore - B. Lippman, Springfield, NJ
fsiburn     Forrest Siburn - Grumman Data Systems, McLean, VA
mbraddy     Marvin Braddy - Springs Ind Research Center, Lyman, SC
nwitthau    Norman Witthauer - Durkopp America Inc, Norcross, GA
malpert     Mel Alpert - Centigrade Chemical Intl, Coral Springs, FL
sewmaste    Sewmaster Inc - Sewmaster Inc, Oceanside, NY
maxantma    Maxant Master Inc - Maxant Master Inc, Oceanside, NY
kikuta      K. Ikuta - Kanematsu-Gosho Inc, Somerset, NJ
tcurle      Tim curle - Eastman Sales
rwaltman    Robert A. Waltmann - Beka (Gebr. Queck)
jmrozins    Joann Mrozinski - Facemate
bhoffman    Bill Hoffman - Halmode Apparel Inc.
tball       Thomas R. Ball - Kuppenheimer Men Clothiers
rorwoll     Richard D. Orwoll - Belding Corticelli Thread Comapny
jboatman    Jeff Boatman - Jantzen
skaufman    Steve Kaufman - Juki America Inc.
jcusiman    Joseph Cusimano - Crown Textile Co.
dmarchio    Doug Marchio - Lectra Systems Inc
eschrama    Ernst Schramayr - Jet Sew  Division of WPP
sfleeman    Ray Fleeman jr. - ARC
mwiseman    P. Marshall Wiseman - Michelman, Inc
rrangasw    Rajamanickam Rangaswamy - Georgia Inst of Tech, Dept of Textiles
```

COMMAND: Mail Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
         Fileservices Transfers Listuser(s) Changepassword Quit Help
    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold   MAIL   2/11/1990 11:17   XENIX
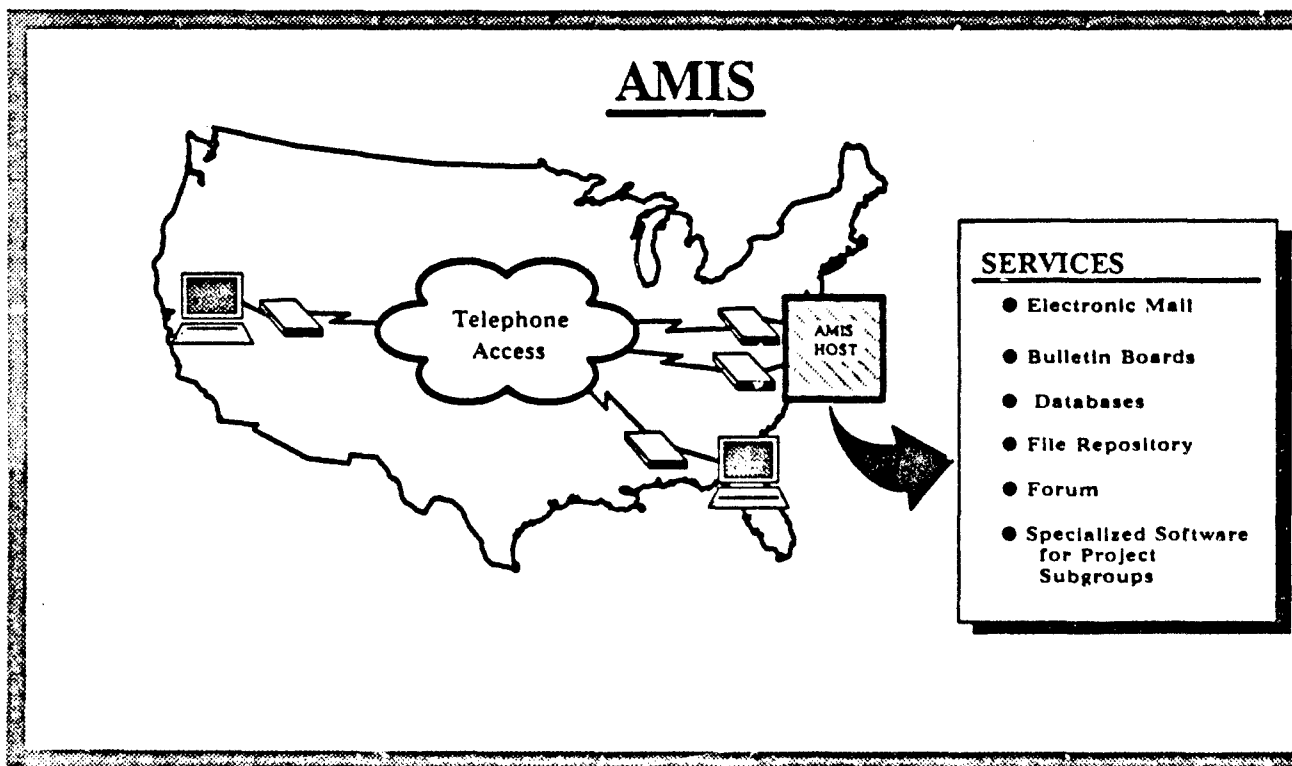

HELP: Mail Other

    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold   MAIL   2/11/1990 11:17   XENIX

HELP MAIL: Mail Sendmail Bulletinboard Inquireboxes ASCII

>> Select option via SPACEBAR or FIRST Letter -- then enter carriage return <<
/usr/acct/harold   MAIL   2/11/1990 11:17   XENIX

The mail system can bo used to:
    1) send mail to other users,
    2) read mail sent to your user id,
    3) file messages in new or existing mailboxes,
    4) access bulletin boards.

Each user has a mailbox called "inbox". Other users can send mail to
your inbox by addressing mail to your userid. You can det~~nine the
userid's of other users via the "Listusers" command, and · · n.r s·nd
messages to them via the "m" command within the mail sys.er.

When you enter the mail function, you are prompted for a ..:.lb.:. ..r.e.
Enter a carriage return for the default "inbox", or enter th: nc.:. ·f
another mailbox or bulletin board. You may use the "Inquirehoxe." command
to list your current set of mailboxes and bulletin boards.

Enter the "?" command after entering the mail system to obtain
additional help on individual mail commands.

HELP: Mail Other

    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<
/usr/acct/harold   MAIL   2/11/1990 11:18   XENIX

HELP OTHER: Database Fileservices Transfers Listuser Changepasswd Quit Keyboard

>> Select option via SPACEBAR or FIRST Letter -- then enter carriage return <<
/usr/acct/harold   MAIL   2/11/1990 11:18   XFNIX

                        FILE UPLOAD/DOWNLOAD

The Transfer facility can be used to upload a file from your PC
to the directory of a user on this system, or to download a file from
this system to your PC. TO USE THIS FACILITY, YOU MUST BE USING A
COMMUNICATIONS PACKAGE THAT SUPPORTS THE KERMIT FILE TRANSFER PROTOCOL.

FILE UPLOAD -- You will be prompted for the following parameters:
    TO: enter userid or userids that are to receive this file.
        For multiple ids, separate by commas or spaces.
    FILENAME: name that the file will be stored under in the user's directory.
    DESCRIPTION: a one line descriptive message of the file that will be
        included in a mail message that will automatically be sent
        to the receiving user(s) after the file is successfully sent.

FILE DOWNLOAD -- You will be prompted for the name of the file to be downloaded
    from your directory to your PC.

The UPLOAD and DOWNLOAD functions will prompt you on when to turn your
kermit tranfer facility on and off.

COMMAND: Mail Sendmail Bulletinboard Inquireboxes Amis-bibliography-search
        Fileservices Transfers Listuser(s) Changepassword Quit Help
    >>> Use SPACEBAR or FIRST Letter of Command to Select Option <<<.
/usr/acct/harold   MAIL   2/11/1990 11:18   XENIX

QUIT

Enter Y to confirm
/usr/acct/harold   MAIL   2/11/1990 11:20   XENIX

The Apparel Manufacturing Information System

The Apparel Manufacturing Information System (AMIS) is a computer-based information distribution system that is being designed and implemented as a part of the Apparel Advanced Manufacturing Technology Demonstration Project at Clemson University. Members of the Apparel Manufacturing community are welcome to use the facilities available on this system and to participate in the information exchange activities that it supports. For more information, please contact:

AMIS System Administrator — (803)-646-8454

AMIS

SERVICES

- Electronic Mail
- Bulletin Boards
- Databases
- File Repository
- Forum
- Specialized Software for Project Subgroups

CLEMSON
UNIVERSITY

FEBRUARY 16, 1990

CLEMSON UNIVERSITY

AUTOMATED FABRIC INSPECTION

Automatic Fabric Inspection System

Objective: To develop the hardware and software so that fabric defects can be automatically generated without human intervention. To integrate the defect map into the actual marker image so recut decisions can be readily made.

Progress to Date: Project was just started. Development of the mechanical defect detection system will be performed as a subcontract to Systronics; anticipated development time is one year. Color and shade defects will be detected by a MacBeth Eagle Eye which has been received. Integration of the defect information will be by faculty in the Department of Mathematical Sciences at Clemson.

System will be installed and demonstrated at CAR.

Time frame: Twenty-four months from January 1990

FEBRUARY 16, 1990

GEORGIA TECH

IN-PROCESS QUALITY CONTROL: FABRIC DEFECTS

IN-PROCESS QUALITY CONTROL
FABRIC DEFECTS

Wayne C. Tincher
Wayne Daley
GEORGIA INSTITUTE OF TECHNOLOGY

IN-PROCESS QUALITY CONTROL: FABRIC DEFECTS

Wayne C. Tincher and Wayne Daley
Georgia Institute of Technology
Atlanta, Georgia 30332

I. INTRODUCTION

Fabric defects are a major cause of irregulars in finished garments. A study reported in 1980 indicated that approximately one per cent of finished garments were off-quality as a result of fabric defects. This loss occurs in spite of several inspections during the course of both fabric and garment manufacturing.

The advent of new spinning and weaving technologies in the textile industry in the past decade has made major improvements in fabric quality. It should be expected that these improvements would result in fewer garments classified as seconds due to fabric defects. However, a recent survey of jeans manufacturing involving over 20 plants suggests that irregulars due to fabric defects in this area of apparel manufacturing continues to run at the one per cent level.

The problem of detecting and removing fabric defects increases in severity as more apparel operations are automated. With fewer workers handling parts, the probably that a defect will be detected decreases. Automated systems for detection and removal of defects are one approach that is being explored to reduce or eliminate fabric and sewing defects in finished garments.

II. THE COST OF FABRIC DEFECTS

Research efforts in the apparel quality area would benefit greatly from a more detailed data base on defects at various stages of manufacture and the economic impact of defect detection and removal at these various stages. Most of the data on apparel defects that have been published report only defects in finished garments. This information is useful but it does not account for the many inspection steps during textile and apparel production and the removal of defects at many points in the production process. At the present time, it is difficult to evaluate the total economic impact of new defect detection technologies due to the absence of good baseline cost data for existing procedures for defect detection and removal.

One study has been reported in the United Kingdom on the cost of fabric defect removal in spreading. This study found that three-quarters of a yard of fabric was lost for each defect removed in the spreading operation. It further suggested that the time required for removing defects was a substantial contribution to the

overall spreading time.

As part of the current project, similar data have been collected on the losses due to fabric defects in spreading of denim fabrics for jeans manufacture. The results are given in Tables 1 and 2. In this study, over one yard of fabric was lost for each defect removed with a total fabric loss of 1.4 %. The actual time loss was 5.8 %, although the time credited to the spreader for defect cutting was 14.2 %. Thus, significant losses in time, material, and seconds are still being experienced by the apparel industry due to fabric defects.

III. AN AUTOMATIC DEFECT DETECTION SYSTEM

Most of the effort at the present time in automatic detection of defects in fabric is directed toward inspection of fabric rolls. A number of companies either have, or will market in the near future, systems for automatic roll inspection. The unfortunate disadvantage of these systems is that if defects are detected they can only be marked (or cut out and replaced by a seam which is another defect). The defect must still be removed with the fabric loss and time loss involved in such defect removal. The approach taken in this project is to automatically inspect cut parts and only remove those parts from the production process which are defective. This approach should significantly reduce the fabric loss due to defects and should decrease the number of fabric defects that go through the entire assembly process and result in garment seconds.

A fabric defect detection workstation has been designed for automatic inspection of cut parts (see Table 3). The workstation consists of five components--a pick and place device to select parts from a stack and place them individually on a conveyer belt, a conveyer belt transport system to move parts to the various inspection stations, a machine vision system (including both line and area camera systems) to inspect parts for fabric defects, a noncontact color measurement system to precisely measure the color of each part, and a take-off device that will reject defective parts and place acceptable parts in a configuration suitable for input to an automated sewing workstation. The system will be under the overall control of a microcomputer for integration of the operation of the various components in the system and for analysis of the collected data to permit decisions regarding the acceptability of each part. The system can also calculate the area and perimeter of each part to determine if the part has been properly cut. Thus, the workstation should insure that only defect free, color matched, and properly cut parts will enter the assembly operations with the parts already configured to feed a automated sewing workstation.

TABLE 1

FABRIC LOSS IN SPREADING DUE TO FABRIC DEFECTS

CUT	DEFECTS	SPREAD (yds)	LOSS (yds)
410	13	925	5.6
411	12	925	12.2
412	11	925	9.6
413	9	925	12.8
151	1	448	0.8
414	20	925	32.8
154	1	640	0.8
155	9	608	11.4
418	10	756	12.8
TOT	86	7077	98.8

LOSS PER DEFECT: 1.1 yds
PER CENT LOSS: 1.4 %

AMTC:1/90

TABLE 2

TIME LOSS IN SPREADING DUE TO FABRIC DEFECTS

CUT	DEFECTS	TIME (min)	LOSS (min)
410	13	50	6.3
411	12	81	4.6
412	11	35	5.2
413	9	55	3.2
151	1	36	0.4
414	20	150	7.7
154	1	60	0.4
155	9	65	3.5
418	10	70	3.8
TOT	86	602	35.1

LOSS PER DEFECT: 0.41 Min
PER CENT LOSS: 5.8 %

CREDIT PER DEFECT: 1.0 Min
CREDITED LOSS: 14.2 %

AMTC:1/90

TABLE 3

CUT-PART INSPECTION UNIT COMPONENTS

PICK-AND-PLACE: JET SEW

MACHINE VISION: IRI SVP 512 AREA CAMERA
                          DIGITAL DESIGN LINE CAMERA

COLOR MEASUREMENT: HUNTER SPECTRAPROBE

CONVEYER SYSTEM: IN-HOUSE DESIGN

TAKE-OFF UNIT: IN-HOUSE DESIGN

AMTC:1/90

IV. AUTOMATIC DEFECT DETECTION

A. Defect Types and Analysis

There are approximately 45 to 50 different types of defects that are found in blue denim. From a machine vision viewpoint they can be placed into two broad classes. These would be defects that show up as contrast differences and defects that materialize as changes in a regular pattern.

These kinds of defects lend themselves to two basic techniques for analysis. The first class of defects is most easily handled using "differencing" kinds of operations. Using this technique measures of conformance to a particular standard are determined and the inspection phase then consists of extracting these measures from each image and then comparing them to the standards.

The second class of defects is handled using texture approaches even though morphological operations might also be appropriate. These techniques are computationally very expensive and methods for simplifying their application will be examined.

B. Imaging

In designing any machine vision solution, two areas of great importance are those of lighting and optics. Attention to these aspects of a design can sometimes mean the difference between success and failure. It was decided therefore to do a preliminary study of these parameters to determine the lighting and optical configuration most suitable for application to fabric defect detection.

In acquiring a camera image the properties of various parts of the system interact to determine the final quality of the image. Some of these characteristics include the light source, the properties of the material being illuminated, as well as the properties of the sensors in the cameras. To determine the overall effect of these interactions experiments were conducted using different light sources and configurations. The aim of the experiments was to find the optimum configuration(s) for conducting automated inspection.

For the tests we the orientations illustrated in Figures 1, 2 and 3 were used. These schemes are in general called direct lighting configurations and the aim is to identify any directional property of the material that could be utilized to enhance the contrast between acceptable and defective portions of the material. Different light sources were also used to span the wavelength range from the ultraviolet to the infrared (this includes the visible spectrum).

Camera   Light

Fabric

FIGURE 1

Camera   Light

Fabric
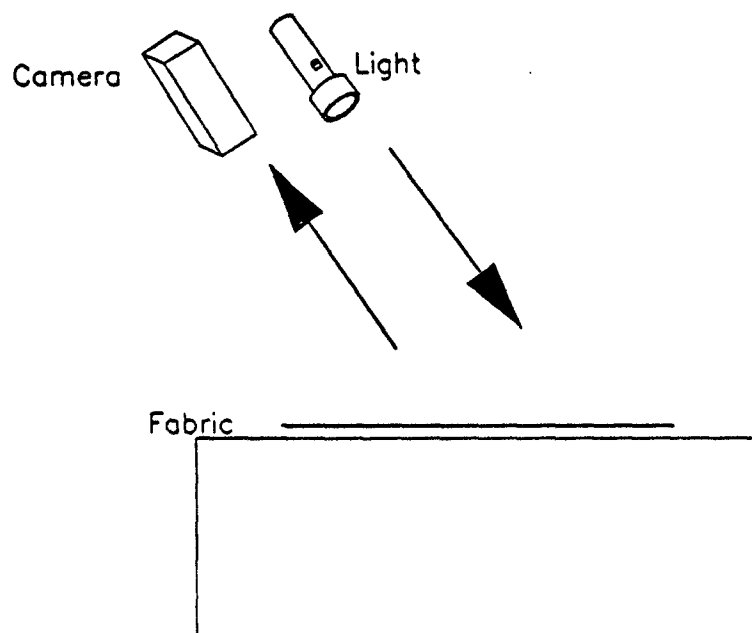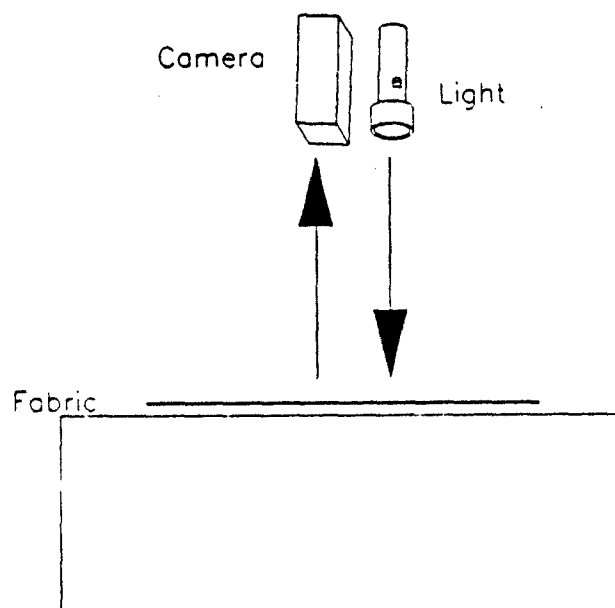
FIGURE 2

C. Tests

The tests were carried out by making reflectance measurements in the orientations shown in Figures 1, 2 and 3, using different light sources. This was done using a spectroradiometer. The relative intensity differences between acceptable and defective segments of the material were then tabulated. In addition, regions in the electromagnetic spectrum that showed noticeable contrast were also noted.

Figures 4 and 5 show sample plots for two tests. Figure 4 shows a substantial difference in reflectance in the 700nm to 800nm wavelength region for a dye streak. The curve for an accumulator kink shown in Figure 5 does not show any major reflectance differences over the wavelength range examined.

This data were tabulated and an ANOVA procedure used to aid in the analysis. The data so far indicate that orientation is a significant factor in determining contrast differences with orientation 0 being the most significant. As would also be expected the type of defect being examined has a significant effect on the contrast differences.

D. Next Steps

The next step in the process will be to verify the spectroradiometer data using our vision systems. Both an area and line system will be used for the tests. In addition we will begin the integration of a test station for conducting real time inspection tests. A detailed investigation of the texture approaches and the algorithms to be considered will also be conducted.

V. COLOR MEASUREMENT SYSTEM

The Hunter Lab Spectraprobe was selected as the color measurement component for the system. This instrument makes noncontact reflectance measurements at 77 points in the visible spectrum (5 nm intervals) at a rate of 15 complete measurements per second. The data can be expressed in a variety of color specification systems and directly loaded into a spreadsheet format for subsequent analysis. The CMC color difference equation will probably be used to determine which samples can be sewn together with no shading problems.

Samples of 60 rolls of Navy blue denim fabric have been obtained and the color of all samples measured. Data plotted in the CIE L*a*b* color space are shown in Figures 6 and 7. These samples all fall in a narrow region of color space and parts cut from many of these rolls should not create shading problems. Samples similar to the ones used in generating the data in Figures 6 and 7 will be used with selected observers to establish the

Camera

Light
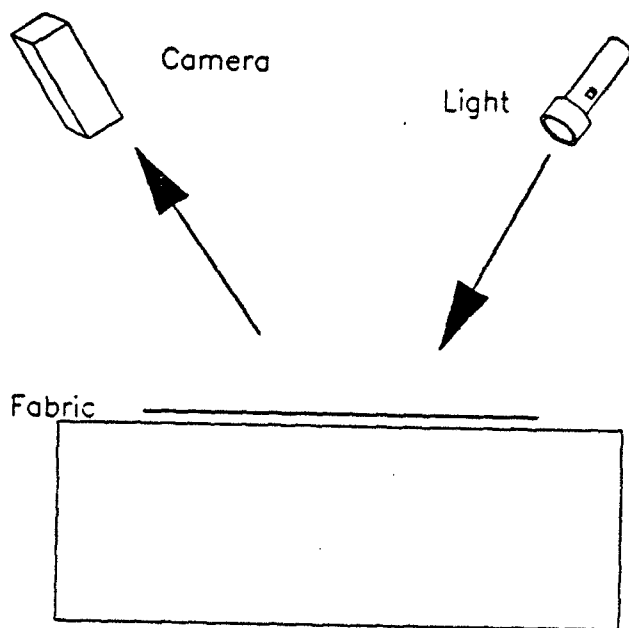
Fabric

FIGURE 3

Apparel Reflectance Data
Dye Streaks

Intensity
(Thousands)

1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

400   500   600   700   800

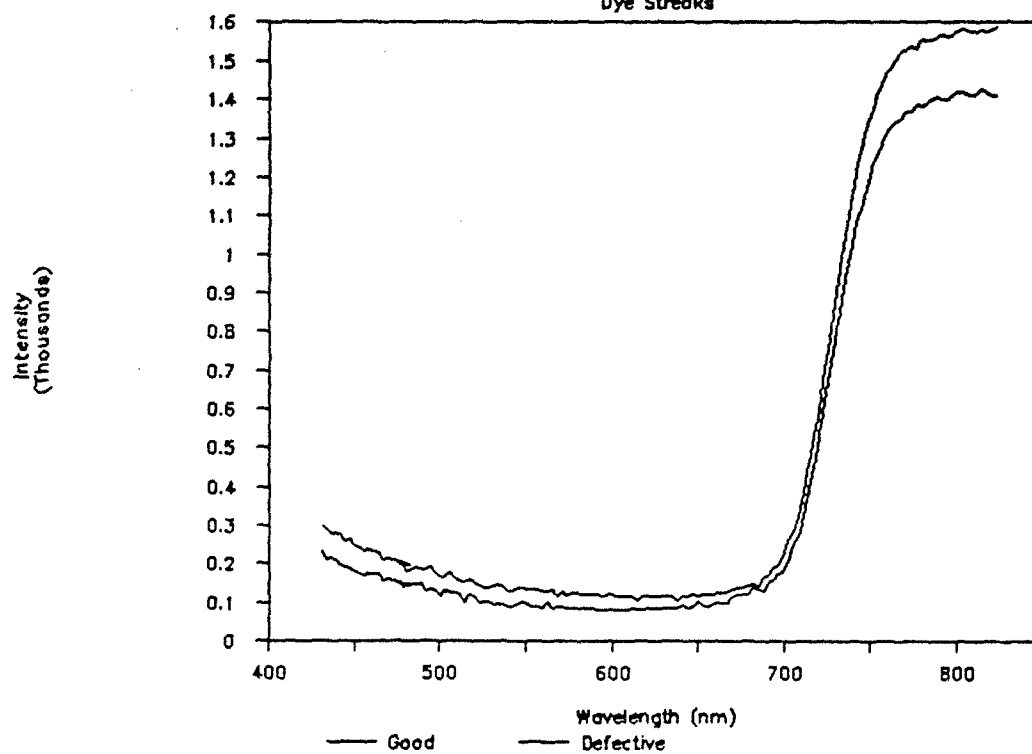Wavelength (nm)

——— Good   ——— Defective

FIGURE 4

Apparel Reflectance Data

Accumulator Kinks
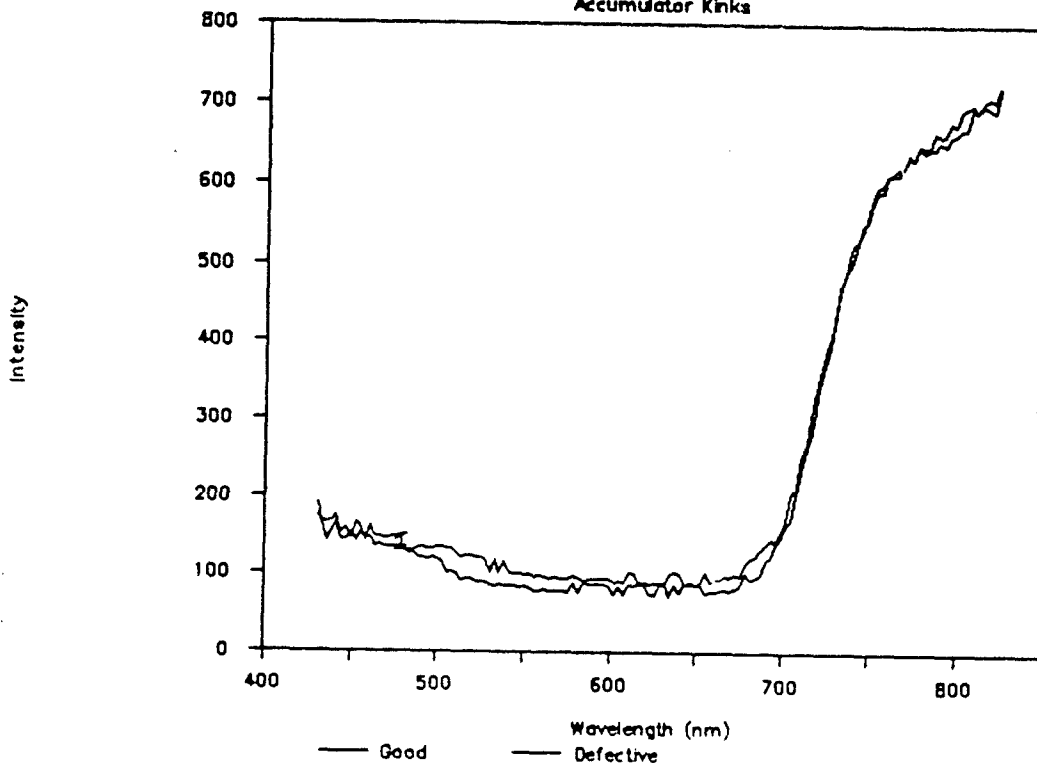
FIGURE 5

COLOR DATA
NAVY DENIM FABRIC
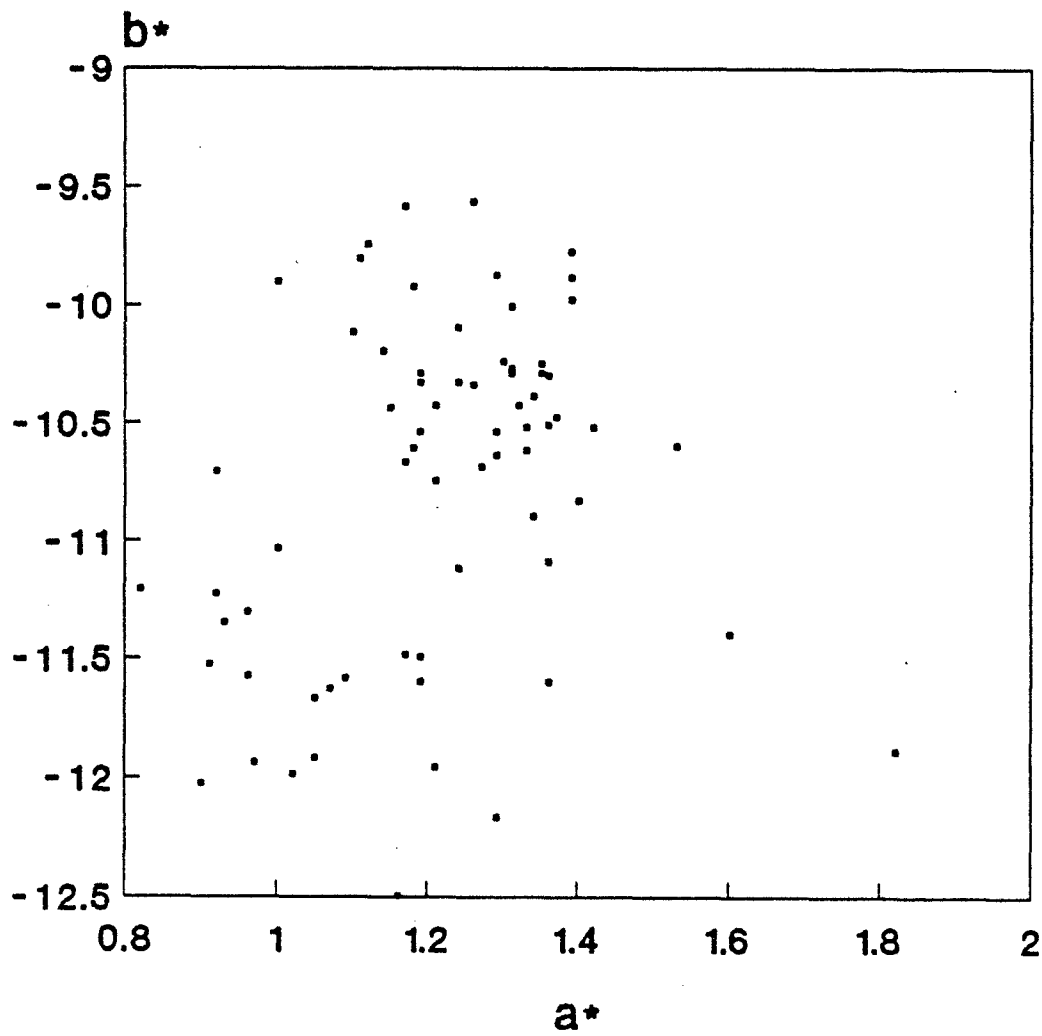
b* vs a*

FIGURE 6

COLOR DATA
NAVY DENIM FABRIC
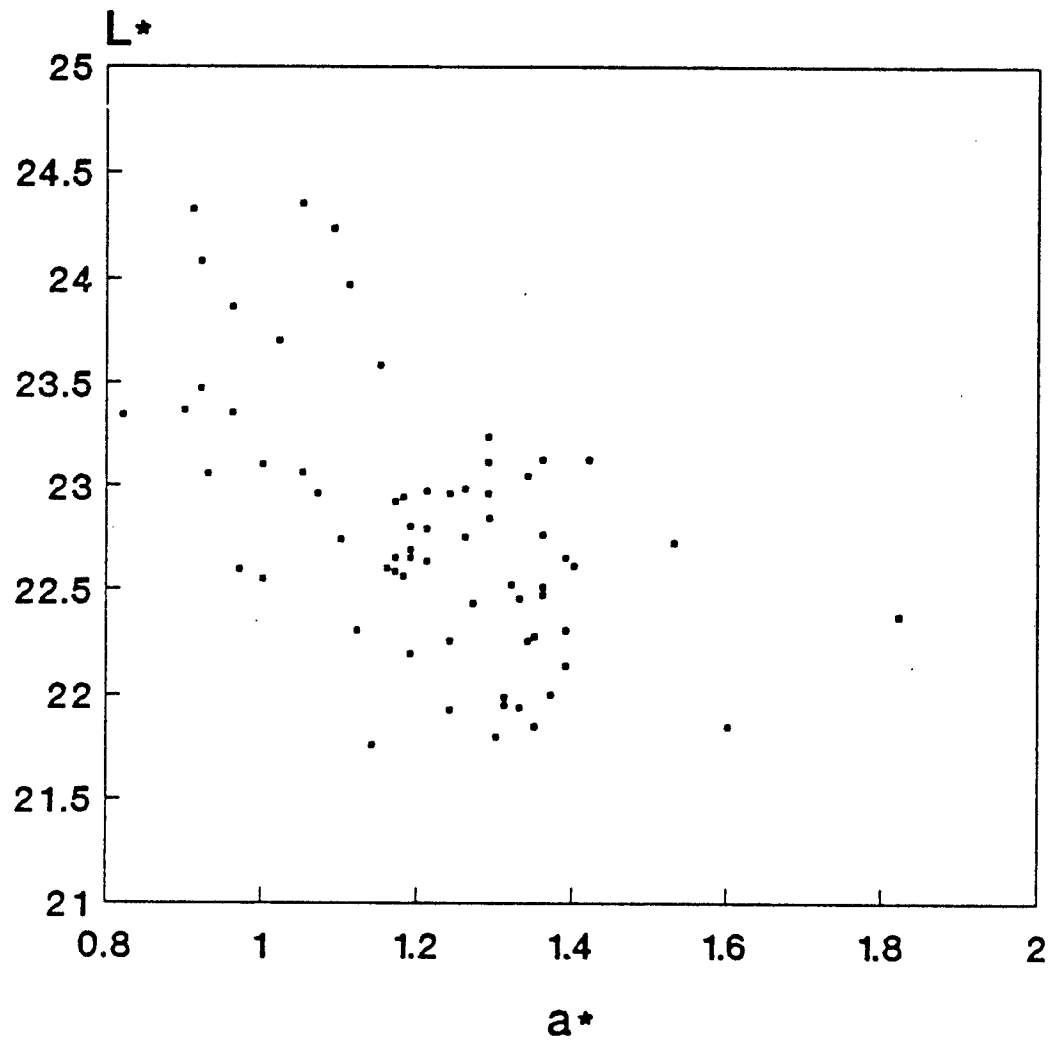
L* vs a*

FIGURE 7

limits in color space of color differences that can be acceptable sewn together in the same garment.

VI. SUMMARY

The project at this time is approximately at the halfway point of the first two phases of the project. The system has been designed, the components selected, and equipment purchased and installed. Work is underway on detection systems for common fabric defects (approximately 100 sample defects have been collected) and on developing the appropriate systems for color measurement and color specification. A third phase of the project is planned to build a cut part defect detection workstation for demonstration at the Georgia Tech-Southern Tech Apparel Manufacturing Technology Center in 1991.

FEBRUARY 16, 1990

GEORGIA TECH

IN-PROCESS QUALITY CONTROL: SEWING DEFECTS

**ADVANCED APPAREL MANUFACTURING TECHNOLOGY
DEMONSTRATION CONFERENCE**

**Philadelphia College of Textiles and Science
February 15-16,1990**

In-process Quality Control In Apparel Production:

Sewing Defects

Georgia Institute of Technology
School of Textile & Fiber Engineering
Atlanta, GA 30332-0295

1.0 INTRODUCTION

This research and development task is directed to providing an automatic, in-process quality control system for the detection of sewing defects as they occur. Preliminary research in the broad area of apparel defects has found that two percent of all production is classified as seconds due to a variety of defects. Sewing defects account for one quarter of the defects with obvious implications to product cost, delivery schedules and customer inconvenience.

Currently, individual sewing machine operators bear responsibility for the detection and correction of sewing defects. At the same time, the operators are under considerable pressure to complete sewing operations on bundles of goods in a timely fashion. Their earnings are keyed to productivity. The operators quality control function in the process of correcting defects conflicts with their productivity goals.

Rapid detection of a sewing defect is important to optimization of the relationship between quality and productivity. Some defects are found only after all apparel assembly operations are completed. Some are found after a subassembly operation is completed. There is significant advantage to identifying a sewing defect and halting the assembly process quickly such that operations of seam removal and resewing are held to a minimum.

On-line quality control is not unique in manufacturing industries. Considerable research has been conducted on sensor technologies and signal processing techniques. This proposed task has available to it measurements of stress/strain, acoustic emission, and light/laser detected vibration, for example, as means of identifying a sewing process signature or profile. There are numerous means for transforming data from a time domain to a frequency domain and applying statistical or reliability constraints.

Recent conversation with an apparel manufacturer's R & D department brought out that a basic process controller used in an automation effort cost $263. While an on-line sewing defect controller may require more than basic controller sophistication, there is still reason to anticipate that a reasonable cost can be established for the system. Patterns for

normal stitches and defective stitches are to be sensed by the controller with a stop signal being generated.

2.0 OBJECTIVE

The primary objective of this project is to develop in-process quality control procedures to detection of sewing defects in assembly of military utility trousers, such as the trousers given in MIL-T-87062A. In support of this objective are the determination of the optimum methods of detecting off-quality sewing, the detection of faults in real time, and the implementation of the detection process in a system which will allow for immediate repair of the seam defect.

3.0 STATEMENT OF WORK

This work is specifically designated to do the following:

a. identify common types of sewing defects in military utility trouser manufacturing;
b. analyze methods of detecting these defects; and
c. develop methodologies and hardware systems to automatically detect and report or remove these defects during the production process.

The statement above identifies three major tasks. Each of these tasks is to be included individually in a major subdivision or phase of research effort. This is discussed more fully later in sections 3.3 on Method.

3.1 DEFINITIONS

3.1.1 Automatic Defect Detection: Identification of off-quality production by means other than human observers.

3.1.2. In-Process Quality Control: Detection of defects before cut parts are placed in production or at the time defects are produced in the sewing operations.

3.1.3. Automated Assembly - Production of subassemblies in automated work cells not requiring an operator.

3.2 Personnel

Dr. L. Howard Olson is the project's principal investigator. Dr. Mathew Sikorski is responsible for data collection systems, and Dr. J. Lewis Dorrity is responsible for transducer electronics and data analysis. The research team management is to allow shared efforts in all areas and communicate at least weekly on progress and objectives.

3.3 METHOD OF ATTACK

To achieve the objective of developing in-process quality control procedures for detection of sewing defects a program of three distinct phases has been undertaken. The goals of these three phases follow respectively the three designations identified in the initial comments of the statement of work - section 3.0, but do include additional supporting effort at each phase.

3.3.1 Phase I - Defects Assessment

The first phase involves identification of sewing defects. Sewing defects must be identified by their physical character, and they must be identified by their signature in an electronically transduced form. The first phase has concentrated on the physical characteristics of sewing defects.

To assist in this, a survey of previous research such as that done at N.C. State University[1] and elsewhere has been conducted. Apparel manufacturers and sewing manufacturers have been visited with the specific goal of obtaining their experience and assistance in characterizing defects. This project is directed specifically to military utility

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[1] Matthews, B. Ann and Trevor Little, "Sewing Dynamics.", _Textile Res. J., 58_, 383.

trousers. Therefore, principal concentration is on those sewing defects and sources of defects applicable to trousers, in particular men's utility trousers. The next section on Phase II discusses this work further.

3.3.2 Phase II - Defect Cause and Detection

The second phase, which is currently underway, involves analysis of the cause for each class of defect found during Phase I investigation and identification of appropriate technology for error detection. Error detection infers here the real time assessment that conditions producing a sewing defect have occurred and production of an error response. Some examples of error conditions are having too few plies of fabric under the needle, sewing off the lateral edge of fabric pieces being joined, and having a break in the bottom thread on a lockstitch seam.

3.3.2.1 General Approach

An old rule of thumb being brought out in quality control meetings is the 85/15 rule which says that 85% of quality problems can be controlled and 15% are unavoidable. Clearly, the assessment process should consider the potential for success in detecting and correcting each type of sewing defect identified in Phase I. Thus, the Phase I defects list can be modified so that the search for appropriate technology to sense and handle defects can be limited to those with sufficient frequency of occurrence and probability of detection and correction to warrant whatever expenditure is necessary. The 85/15 rule may be modified in its statement that a realistic sewing defect identification system will find 85% of defects as they occur while leaving 15% undetected. This may be realistic; of course, the goal is 100%.

To achieve the goal of error condition identification, a variety of technologies are known. Some have arisen from non-destructive testing techniques. For some years, the acoustic signature of engines and machines has been used as a means of detecting parts wear and failure. Textile weaving machines are being sold with this approach to self-diagnosis of faults, identifying individual bearings by their acoustic

signature when failure is eminent. This approach has the advantage of potentially detecting several classes of faults. The acoustic emission from needle penetration should combine factors such as number of layers of fabric, sewing thread size and type, and fabric characteristics in producing a specific spectrum of sound. Thread line tension and thread line vibration detected by, for example, IR devices can carry similar or different information from that obtained by acoustic emission.

With an array of possibilities for sewing defect detection, this Phase of effort must arrive at an optimum means to accomplish the goal. Practical considerations include sensor size, sensor sensitivity to the industrial environment, sensor interface to a computer or controller, and sensor cost. The industrial sewing machine is reasonably compact and limited in internal free space. The external space used during sewing for the flow and control of fabric layers being joined is critical as well. An industrial sewing machine varies in speed from 1,500-5,000 RPM. It is in an electrically noisy environment, and there is usually lint and dust generated by the sewing operation. Sensor selection must assess these factors, their effect on the sensor, and arrive at one or more means of obtaining the information needed for the error detection system. Then the necessary matters of interfacing and cost can be added. This phase should produce a list of sensor technologies that should be used in the investigation conducted in Phase II of the work.

Defects considered should include:

a. skipped and misformed stitches,
b. missing or misfolded parts,
c. improper and wavy stitch margins, and
d. broken stitches.

This does not limit the number of defects considered, since more may be found.

Visits were undertaken to DCASR/DCASMA persons responsible for quality, apparel manufacturers, a machine manufacturer's R & D center, and to the apparel research lab at N. C. State University. The Bobbin Show had a skipped stitch detector on display, and Trevor Little at N.C. State

demonstrated a Pfaff machine with a force transducer incorporated into the needle bar.

The results of questions to manufacturers about sewing defects were interesting in that a central, or unified list of sewing defects was not found. One manufacturer (shirts) had detection of number of fabric plies as its priority item, another (trousers) had seam alignment as its priority. All were interested in needle condition and thread breakage. Another defect appeared to be caused by slippage of the fabric under the presser foot and was characterized by excessive stitch density over a short distance. Little was volunteered about long term problems or about records on sewing defects. Therefore, rather than relying on history, the sewing defects come from current lists of defects and from watching returned goods inspection for defects that were attributable to sewing. This work is not completed as the research team is preparing a list of defects to present to apparel manufacturers for a second round of discussion and comment.

3.3.2.2 Acoustic Emissions and Analysis

The first efforts have been to acquire acoustic emissions data and begin investigation of analysis techniques. Initial efforts looked at data sampling rates, an effect termed aliasing, and filtering of signals. This is discussed briefly below.

Data Sampling Rates

The analysis of data from engineering experiments has been greatly facilitated by advances in computer and software technologies. One of the main steps in such analysis is to digitize the signals from transducer devices. In doing this, one must be aware of the Nyquist (sampling) Theorem. This theorem states that the minimum frequency which can be used for digitization without losing information is twice the highest frequency of interest. This is described in many texts and one which describes well the reasoning behind the theorem is Kuo[2].

Kuo derives the transformation from the time domain to the frequency domain which shows that a sampler is a harmonic generator. The author illustrates the replication of a signal spectrum at intervals of the sampling frequency, ω_s. As ω_s approaches the highest signal frequency, ω_c, the sidebands begin to overlap the original signal spectrum thereby giving erroneous results. The closer the frequency of interest is to ω_c, the more erroneous the results. Thus the theoretical limit is as stated above. Practical filter design makes it prudent to sample at a somewhat higher rate, perhaps $\omega_s > 3\omega_c$. A filter with a cutoff frequency "close to" the highest frequency of interest should be employed to prevent this from occurring.

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[2] Kuo, Benjamin C. *Analysis and Synthesis of Sampled-Data Control Systems*; Prentice-Hall 1964.

Aliasing:

Another problem which can occur in digital sampling is called "aliasing". This is a phenomenum which causes a frequency to appear to be a much lower frequency. This may be visually observed when using a strobe light with a rotating object. When the flash (sampling) frequency is much lower than the frequency of rotation, the object appears to be rotating at a different frequency than it actually is. The figures below illustrate the problem.

The two figures on the following page are samplings of the same signal. The original waveform is shown at one sampling rate while the "Alias signal" is sampled at a rate one-fifteenth as fast. This causes the observed frequency to be much less than actual.

At first the two problems discussed above may appear to be the same phenomenum. However, in the first case we have a non-existent waveform appearing superimposed on a real waveform and in the second case we have an existing waveform which appears to be at a different frequency than it actually is.

Filtering: From the above discussion it is seen to be necessary to attenuate those frequencies which are higher than those in the region of interest. This may be easily done electronically by using operational amplifiers and appropriate feedback circuits. In this method the filtered waveform is sampled and analyzed. Digital filtering may also be employed by appropriate software algorithms in the computer. If realtime processing is needed and the sampling rates are too high, the algorithm may not be fast enough. One must also be aware that real filters are not ideal and frequencies near the cutoff of the filter may affect results if they have a large amplitude.

ORIGINAL SAMPLED WAVEFORM
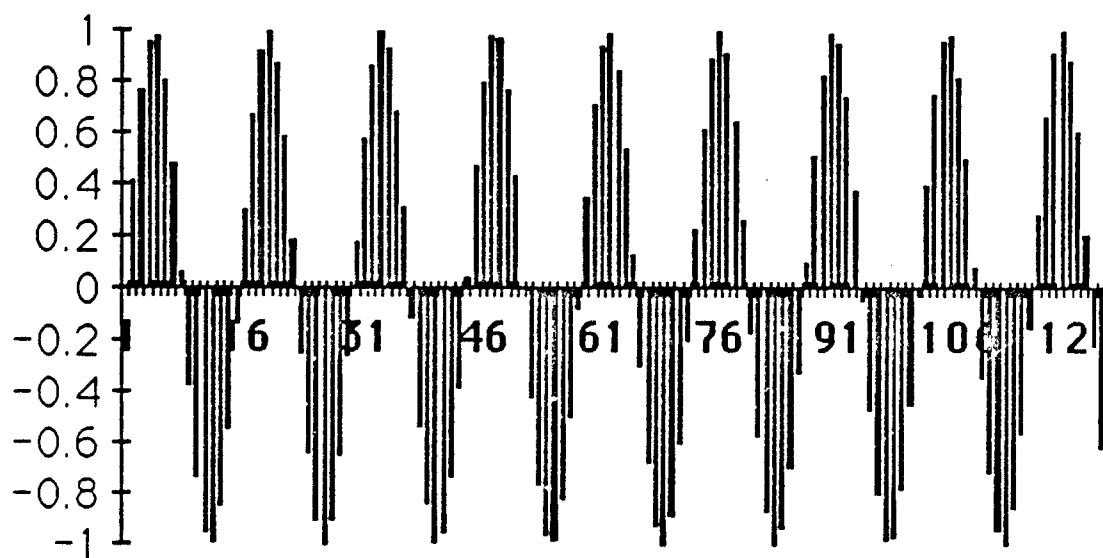
Figure 1.

ALIASED SIGNAL
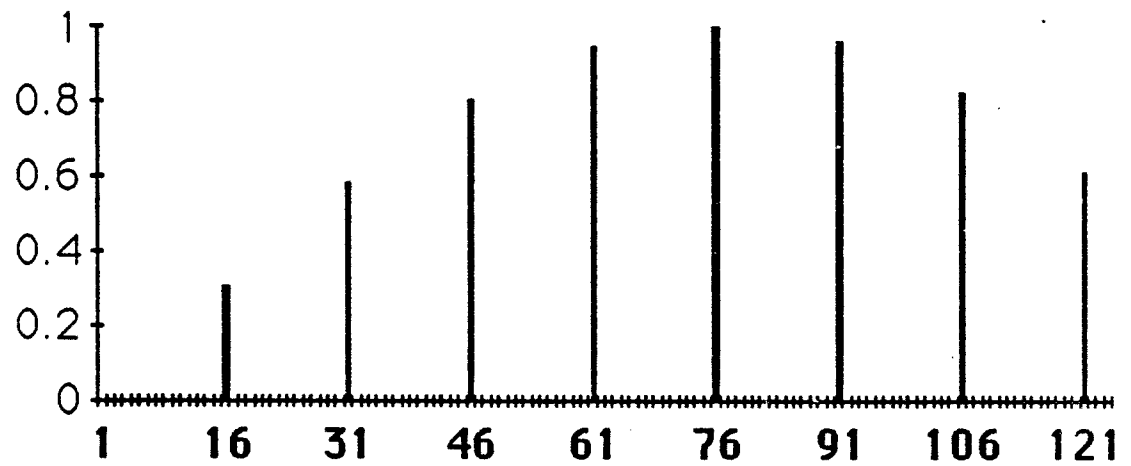## (Plot of every 15th point of original signal)

Figure 2.

3.3.2.3 Sewing Machine for Data Acquisition

A JUKI single needle lockstitch industrial sewing machine was received from the JUKI America R & D Center in Duluth, GA. The machine is a DDL-5550-6 series machine with a SC-320 controller. The machine is adjustable from a high of approximately 4900 stitches per minute to about 100 stitches per minute. The controls on the SC-320 allow changes in 400 s.p.m. increments with fine changes within increments. The effect of machine speed on acoustic response is one of the variables that will be investigated in the immediate future. The ability to measure and record the sewing speed is important. The machine is equipped with an automatic thread trimmer and a motor that is stable in speed.

3.3.2.4 Initial Data Acquisition

The purpose of the initial efforts at data acquisition were to test the acquisition system and the data packages. The JUKI sewing machine provides in the electronic controller a top of cycle or bottom of cycle pulse for triggering data acquisition. A more sophisticated trigger source will be needed for future work. Included below successively are figures of a signal made while the machine is running over a single layer of fabric and a noise signal amplified to be of similar amplitude to the running signal.

Signal Data

Original Data
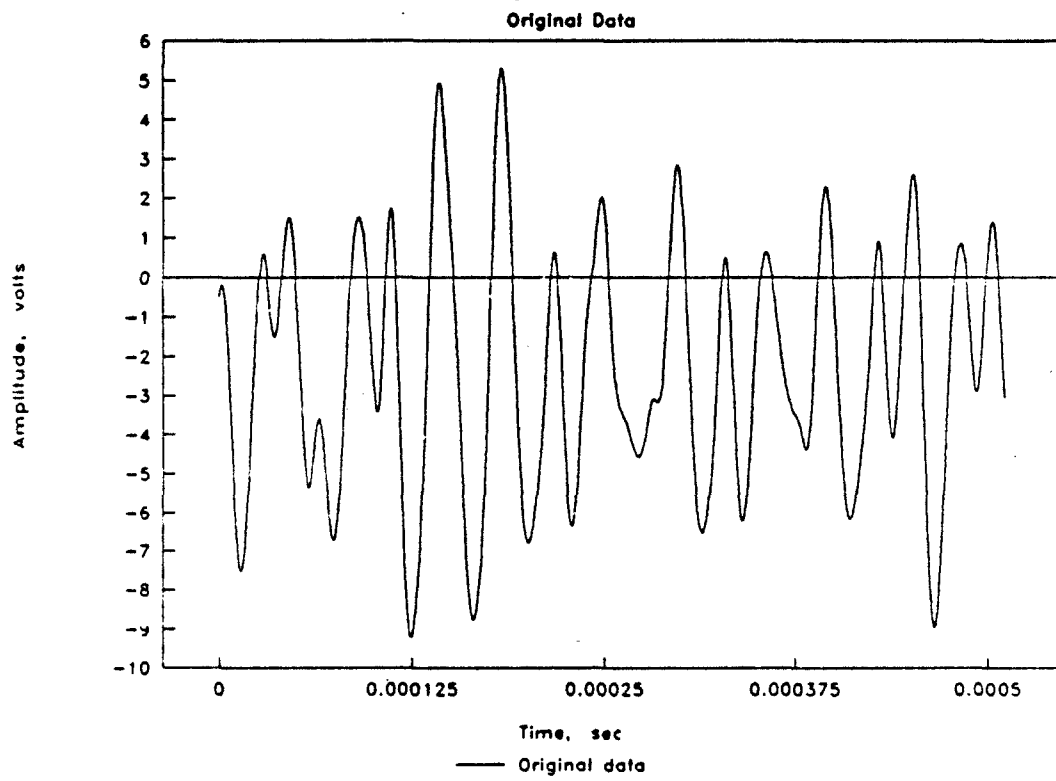
Figure 3.

The noise image similar to the above in Figure 3 is shown in Figure 4 following.

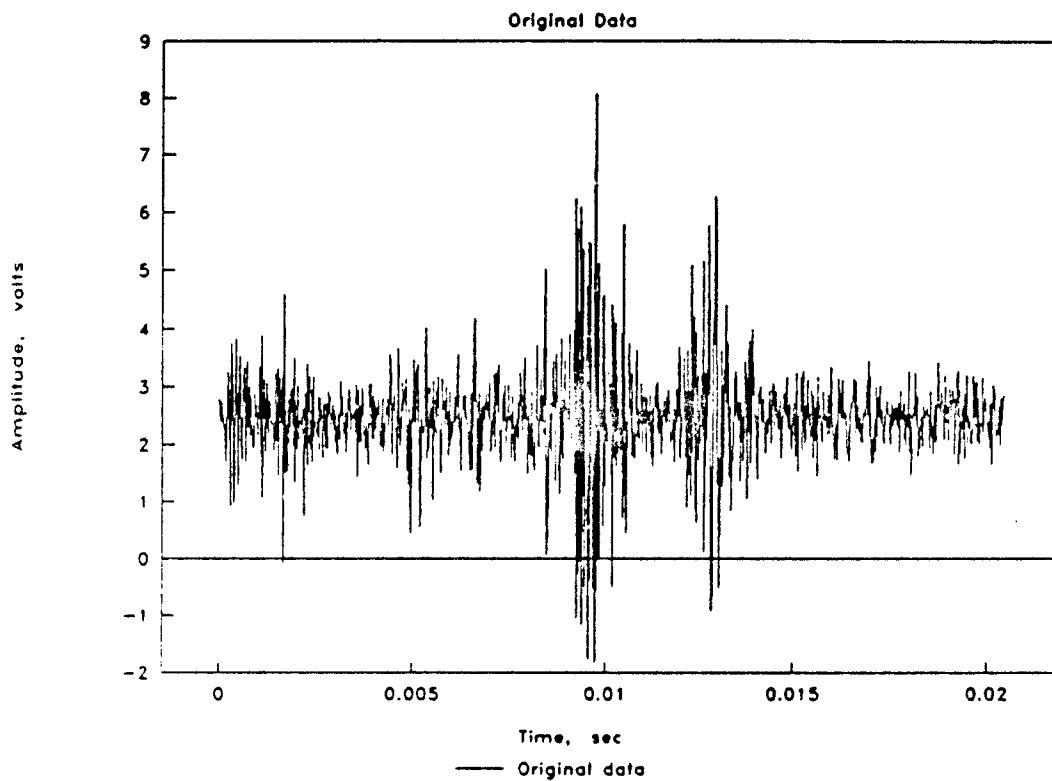## Noise Signal

Original Data

Figure 4.

Both images have the same number of data points and the same sampling frequency (1024 points, 500ns interval). Expanding the noise signal leads to finding what appears to be periodic information. The true test of noise versus interesting content comes with analysis by means of the Fast Fourier Transform (FFT) and the spectrum (normalized, real portion).

To illustrate this, the spectra of both Figures 3 and 4 are represented respectively by Figures 5 and 6. These follow on the next page.

Signal Spectrum
Original Data

Figure 5.

Noise Spectrum
Original Data
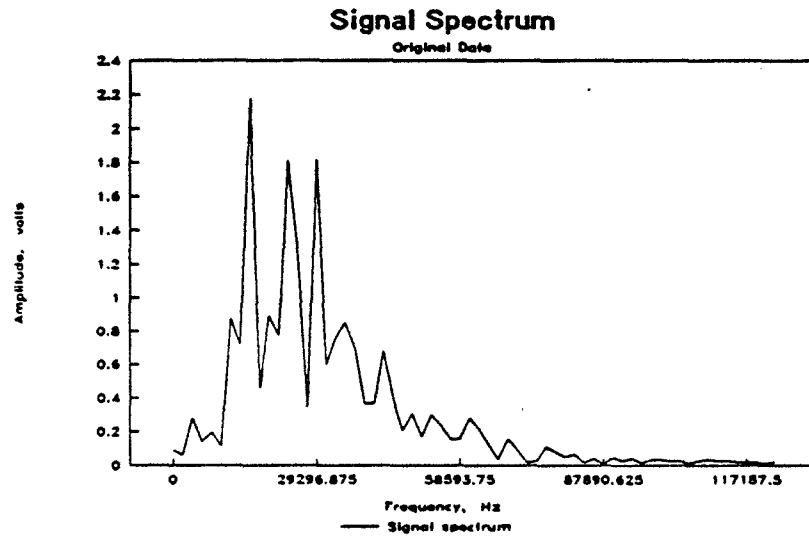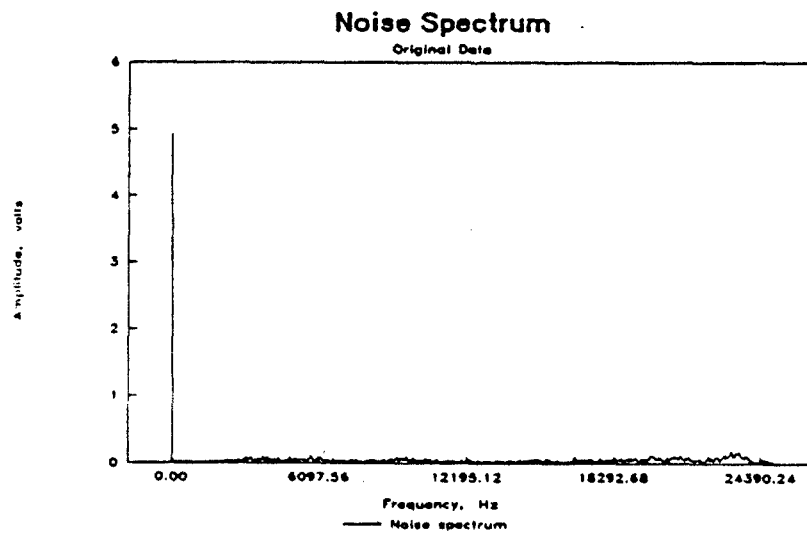
Figure 6.

The spectra clearly show which has periodic signal content and which has none. The noise signal rests on or at the zero axis, indicating no amplitude was found at any particular frequency. The operating signal has something happening at 15 to 30 kHz and perhaps harmonics or other signals at 45 to 60 kHz.

The FFT is done on periodic functions. The fixed interval data sample has discontinuity at the ends. There is an effect on the spectrum caused by the energy artificially generated by the data edges. Routines which taper the end points of a non-periodic signal so that they match is referred to as a windowing function. Several known by name are the Hamming, Hanning and Kaiser functions. To see the effect of the window on the signal spectrum, the following two figures give the data equivalent to that in Figure 3 and Figure 4 with the Hanning window applied.
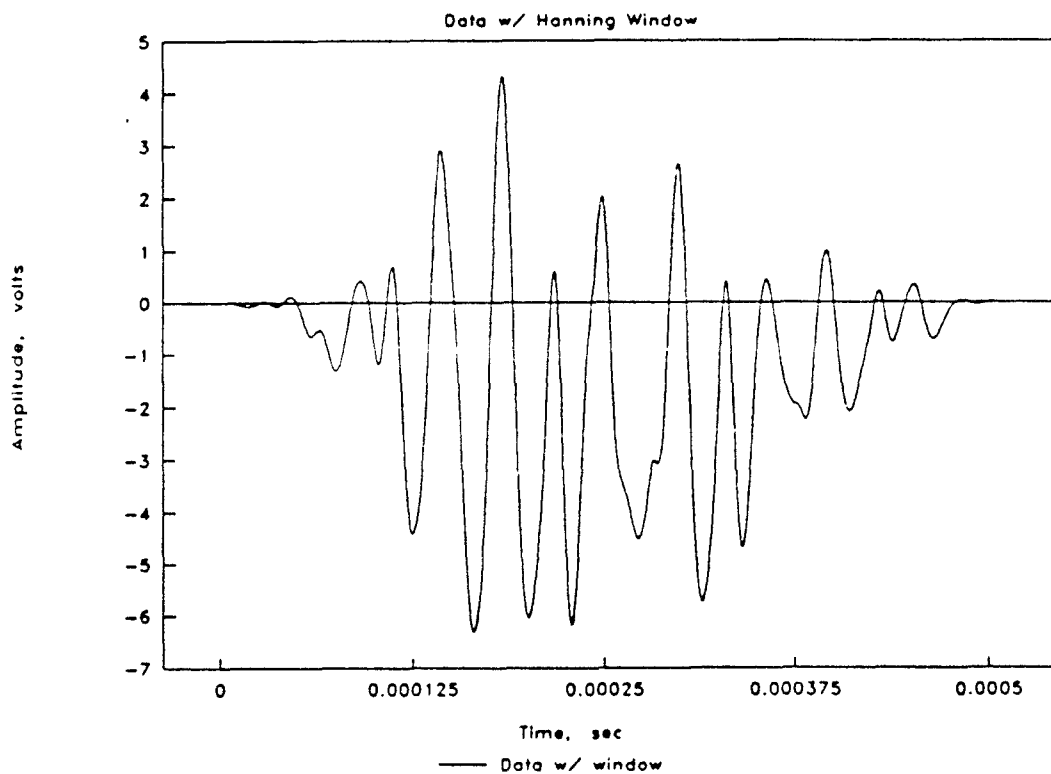
Signal Data

Data w/ Hanning Window

Figure 7.
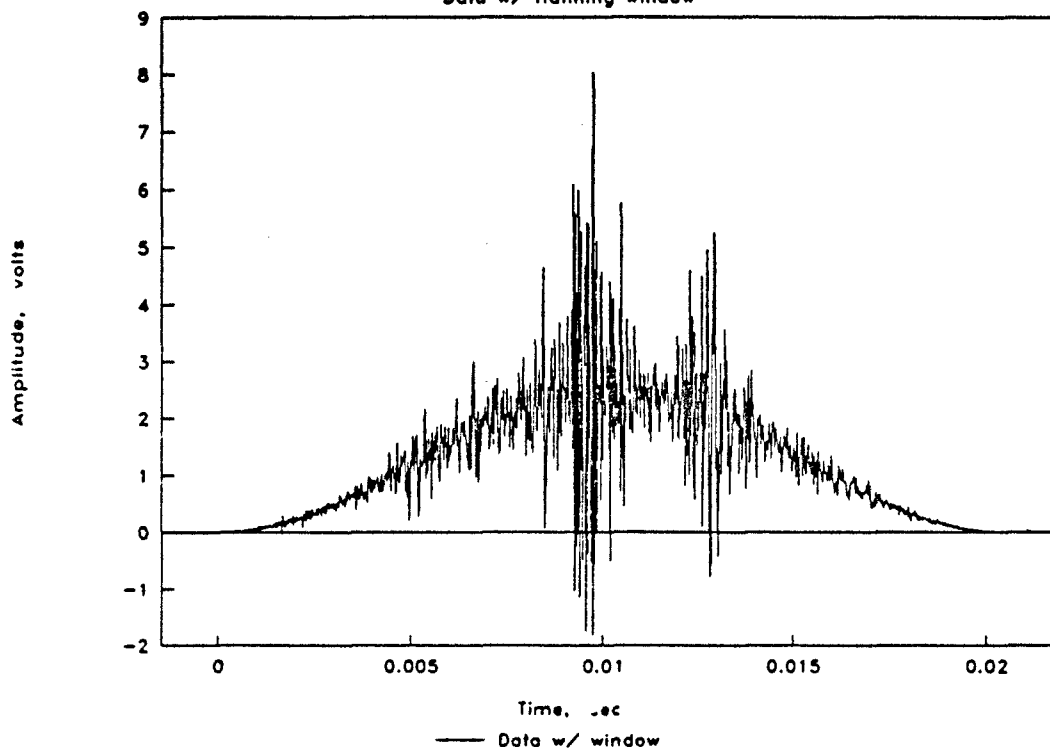
Noise Signal

Data w/ Hanning window

Figure 8.

Figure 7 above indicates only the shape of the windowing function when compared to Figure 3. The purpose of doing this is to determine if windowing alters the spectrum. The next figures, Figures 9 and 10 on the following page, illustrate the spectrum for signal and noise after windowing.

Superimposing the spectrum pairs with and without windowing shows that the frequencies remain intact. Amplitude is changed somewhat for the signal data, but that significance is not certain at this time. The immediate result of this brief analysis is that windowing will not be necessary. Nevertheless checks will be made to be sure.
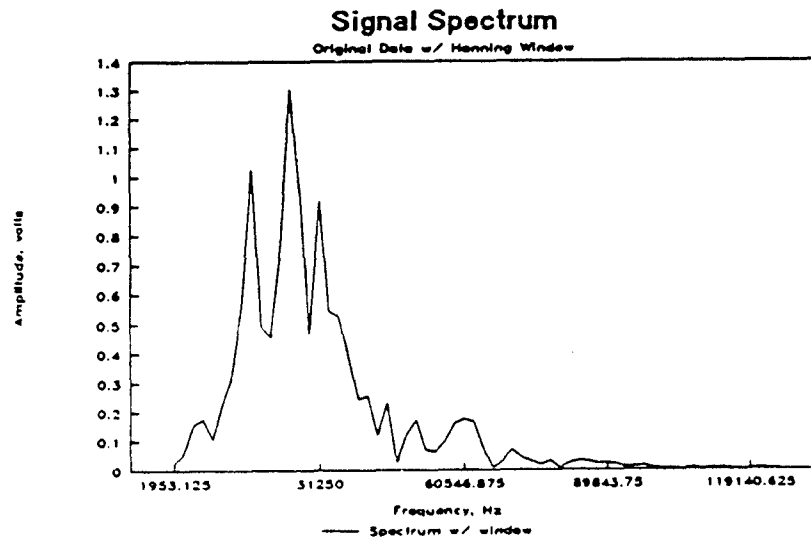
Signal Spectrum

Original Data w/ Hanning Window

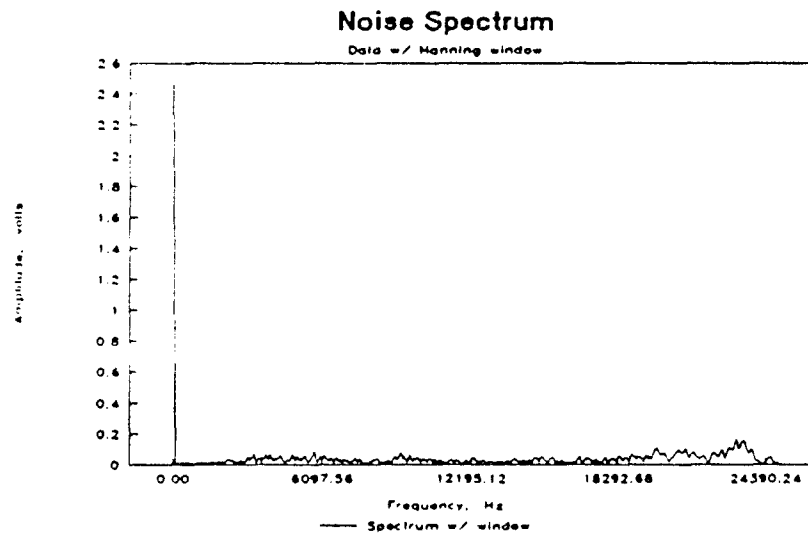Figure 9.

Noise Spectrum

Data w/ Hanning window

Figure 10.

Working with data like that in the above figures and studying their complexity suggested that random and external noise may well be a component of what is being seen. This does indicate that techniques such as averaging of data over five or ten cycles, or, more simply, averaging several successive spectra may be useful in detecting more clearly where changes occur due to process changes. There is a significant amount of process and random noise outside the acoustic energy related to process change for which detection is needed. This is part of the early work necessary to set up efficient investigation of sewing defects.

3.3.2.5 Data Collection Equipment, Transducers, and Software

Data above were collected with a Nicolet 2090 digital recording oscilloscope. Due to data format incompatibilities with the PCs being used for analysis, a Nicolet 310 is to be used for the near future. A data collection board for the PC from CyberResearch capable of four channel, one MHz sampling will be substituted later for the Nicolet. The assumption is that in the end a computer based system will have to do all the work from collecting data to signalling that a defect has occurred in a single system. Therefore, consolidation of external equipment into a single PC environment is one of the tasks constantly under review.

A thread motion detector from Eltex in Sweden is delayed by the manufacturer while some final problems are removed. This was shown at the Bobbin show and Dr. Sikorski undertook immediately to follow up with the company with an indication of our interest and information on this project. An integral of the acoustic signal from this device may give results proportional to thread consumption. If this proves true, then information on missing bobbin thread, missed stitches, and misfed top thread may be had.

Also, a device, the Datafil type SR20 Thread Breakage Detector, designed to record thread breaks by means of a logic level output has been obtained. The problem with thread break detectors traditionally is that a vibrating thread column crosses the line of detection and occasionally leaves the region of detection, leading to false stop signals. This device

is intended to respond to a vibrating thread column.

The data acquisition system for acoustic emission consists of Physical Acoustics and Spectral Dynamics transducers and signal conditioning equipment, a Krohn-Hite electronic filter and Nicolet Instrument Corporation Model 310 digital oscilloscope. The electronic signals recorded on 3.5 inch diskettes are subsequently analyzed with the help of commercial DADiSP and Igor software using MS-DOS PC and Mcintosh equipment, respectively.

The Physical Acoustics Corporation acoustic emission system consists of Model 1220A preamplifier with a 40/60 dB gain capability, Model AE1A amplifier with a variable gain of 0-41 dB and three transducers to evaluate signals in different frequency ranges. The smallest transducer (3/8 inch diameter), Model S 9223, has a frequency range of 20 to 100 kHz. Because of its relatively small physical size, it can be placed in the vicinity of the sewing needle for ultrasonic energy pickup. Two additional transducers are: Model R-15/C with a nominal frequency range of 50 to 200 kHz and Model WD(wide band) to cover the range of 100 to 1200 kHz. The diameters of these transducers are 5/8 and 11/16 inch, respectively. Various materials are available to provide acoustic coupling between parts of the sewing machine and the transducers. These include elastomeric as well as epoxy couplants.

An accelerometer model M-99-1 from Spectral Dynamics (San Diego, CA) for an SD 340 micro FFT analyzer has a frequency response of 1 Hz to 21.6 kHz with a tolerance of $\pm$ 3dB. It measures about 7/8 inch in diameter and it screws into a 2-1/8 inch diameter base. Its low frequency response may prove important and fills the low end gap in the frequency spectrum of transducers available to this project. The transducer base has a magnetic hold down which can be used to couple the transducer to the bed of the sewing machine. This arrangement is expected to yield information on the lowest frequency vibrations or sounds generated by the sewing machine in operation.

The electronic filter used is a Krohn-Hite Corporation Model 3550. It is a multifunction filter operable in a band-pass, band-reject, low-pass, or high-pass mode. Cutoff frequencies are independently adjustable

between 2Hz and 200 kHz.

3.3.3. Phase III - Technology Demonstration

The third phase involves demonstration of the technologies identified in Phase II in detecting defects identified in Phase I. This effort is clearly intended to duplicate the manufacturing environment. A flexible design base should be found so that investigations can follow more than one course and find the optimum set of sensors and data reduction techniques for defect capture.

To accomplish this, a high speed computer will be employed in the experiments such that an excess of data will be available for analysis. One aspect of the analysis is to find for one type of seam the minimum data rate, data volume, and sampling time that will produce reliable results. Data transformation is also subject to investigation, e.g. choosing an appropriate handling of the fast Fourier transform.

Signal conditioning consolidation should be accomplished with commercially available equipment, but hardware can be designed and manufactured by the Georgia Tech investigators if needed. Normally, modern sensors are sold as computer ready, or newer data interface boards and A/D converters have the range and scaling to adapt to sensor limitations.

After a sensor set and data reduction technique have been identified, a decision point will arise. The ideal path is to convert the software to reside in a small industrial controller with appropriate I/O cards for the task at hand. If the expenditure of effort and time to transfer to a controller preclude this step, the high speed system will be optimized and tested for reliability with respect to false stops and failure to detect errors. A feedback loop from the tests to the hardware design and software function should clear to an acceptable level both false readings and detection failures. This is more commonly known as debugging.

The system after development will be set up for demonstration to apparel manufacturers. The demonstration center at Southern Tech is the

preferred site for the demonstration. Also, those manufacturers who cooperated with the project will be given a on-site preview of the apparatus where feasible. Their input to evaluating its performance will be of benefit to the research team.